THE JOURNAL

OF THE

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

Chas. Bullock, Prof. Persifor Frazer, D.Sc., Prof. Edwin J. Houston, Theo. D. Rand, Prof. Coleman Sellers, Committee on Publication:
with the Assistance of
Dr. Wm. H. Wahl, Secretary of the Institute.

COLLABORATORS:

Prof. L. D'Auria,
Prof. Wm. H. Greene,
Prof. Lewis M. Haupt,
Prof. Chas. F. Himes,
Carl Hering.
Dr. S. C. Hooker,
Prof. Geo. A. Koenig,
Otto Lüthy,
Prof. Wm. D. Marks,
Prof. S. C Sadtler,
Prof. M. B. Snyder,
H. W. Spangler, U.S.N.,
Prof. Henry Trimble.

VOL. CXXVIII.—Nos. 763-768.

THIRD SERIES,

VOL. XCVIII.-JULY TO DECEMBER, 1889.

PHILADELPHIA:
Published by the Institute, at the Hall, 15 South Seventh Street.
1889.

JOURNAL OF THE FRANKLIN INSTITUTE.

Vol. CXXVIII.

INDEX.

JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA,
FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVIII. JULY, 1889. NO. 1.

MACCOY'S PNEUMATIC TOOL.

[*Report of the Committee on Science and the Arts.*]

[No. 1478.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 28, 1889.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

MACCOY'S PNEUMATIC TOOL.

Report that: This invention consists in an automatic hammer reciprocated in a cylinder by compressed air or by steam, and delivering a rapid succession of blows upon a tool-holder, into which are inserted suitable bits or chisels for cutting wood, metal or stone; and embraces in its details valves for admitting and exhausting the air, a provision for relieving the cylinder and piston from injurious friction and for cushioning the piston and holding the bit-socket in posi-

tion to facilitate its easy and steady application to the work. As exhibited to the committee, it was working at a very high speed, from the pitch of the sound probably more than five thousand strokes per minute. (*Figs. 1–7.*)

The instrument, as complete and connected ready for action, appears in the form of a short cylinder, having a flexible tube centrally connected to one end, through which compressed air or steam is supplied at a pressure of about forty pounds per square inch, and centrally at the other end, a guide or sleeve, in which the tool-holder reciprocates; into the socket of the tool-holder the cutting bits, chisels or hammers are inserted.

Upon disengaging a latch by pressing a button, the ends of the cylindrical case can be unscrewed, and inside of the shell or cover is found a working cylinder, with grooves on its outer surface and passages leading from the flexible tube at the centre of the upper cylinder head to one slotted chamber in the outside of the working cylinder and terminating in inlet ports leading into the interior of the working cylinder.

Another slotted chamber in the external surface of the working cylinder leads from reduction ports through the cylinder and terminates in a channel leading to the atmosphere through the head of the cylinder.

The piston is made long and fits fluid-tight, but with a minimum of friction in the cylinder.

In the piston, but working transversely through it, is a piston valve which is worked by the pressure of air admitted through the port in the side of the cylinder and exhausted through other ports in the same manner as the piston valves of some steam pumps, the proper ports in the cylinder being covered and uncovered by the motion of the piston. The valve consists of a cylindrical plug having two grooves formed therein with a collar between them, and fits in a cylindrical transverse seat in the piston and covers and uncovers, at proper intervals, admission and exhaust ports leading to the ends of the working cylinder.

The piston is not attached or connected to the tool-holder, but strikes upon it as a ram or hammer; a spiral

spring placed around the tool-holder, and resting with one end on a shoulder in the guide, and with the other end on a shoulder in the tool-holder, serves to retract the tool-holder; the upper end of the tool-holder has an expanded head, fitting loosely in the head of the working cylinder and receives the blows or strokes of the piston.

As the piston rises and falls in the cylinder it closes the ports and incloses a portion of the air between it and the ends of the cylinder, and thus forms an elastic cushion and relieves the operator of the shock of reversing the motion of the piston.

The piston is surrounded constantly by a film of air under pressure, and whilst not leaking appreciably, seems to sustain little or no wear, notwithstanding the rapid motion.

The effect of the rapid and short strokes on cutting tools upon stone, wood and metal, is to produce a smoother surface than has heretofore been practicable with chisels, and with a celerity unapproached by other means. It has a capacity to reach into angles inaccessible to rotative tools.

It has been applied successfully to the caulking of steam boilers, the chasing of silverware, *repoussé* work, stone dressing and sculpture.

The discovery of a new, rapid and cheap method of cutting and forming stone and metal, and the perfection of an apparatus to successfully apply it in the arts is, in this case, the real invention.

The invention is the subject of letters-patent of the United States, No. 373,746, November 22, 1887, granted James S. MacCoy for the new method, and United States letters-patent, No. 205,619, dated July 2, 1878, granted Samuel W. Dennis for a motor for dental pluggers, and United States letters-patent, Nos. 323,053 and 326,312, respectively, dated July 28, 1885, and September 15, 1885, granted to James S. MacCoy for his pneumatic tool.

As applied to caulking and chasing, and forming sheet metal, it surpasses in both ease and rapidity of work and perfection of finish all other implements; and as a practically useful machine, with a wide range of applicability in

the arts, it commends itself as deserving of the highest recognition as a valuable improvement.

Having in view the high claim which this invention has by its demonstrated utility, your committee deem it expedient for a clear understanding of the invention, that the prior state of art under which it is introduced should be examined and reported upon.

In investigating into this part of the subject, your committee have made an examination of the entire classes of inventions known as rock drills, pneumatic drills, steam hammers and pneumatic pluggers, as exemplified in the drawings of the United States letters-patent from the earliest to the present time, and have made selections of such as throw light upon the subject, which they submit in chronological order, in an appendix to this report.

In them they find isolated parts of the invention, but do not find the combination which produces the perfected result demonstrated by Mr. MacCoy's invention.

First of these is James Nasmyth's steam hammer. patented April 1, 1843, No. 3,042. This, whilst showing a cushion below the piston and a spiral spring above it, shows the ram with a long and slow stroke permanently attached to the piston rod, and in this respect differs radically from MacCoy's device (*Figs. 8–10*).

Bannister and Green's United States patent, No. 71,950, dated December 10, 1867, shows a double-acting piston, operated by compressed air and directly attached to a plugging tool-holder for compacting the gold foil in plugging teeth. In this device the plugging tool must move the entire length of the piston stroke (*Figs. 11–14*).

In both of the devices above noticed, the valve for controlling exhaust and inlet of the propelling fluid is a separate piece from the piston and receives motion therefrom only at intervals by a connecting mechanism.

In David Joy's United States patent, No. 80,550, dated August 4, 1868, for steam hammers, the admission and exhaust valves and passages are formed in the hollow piston rod, which rod is permanently attached to the ram (*Figs. 15, 16*).

E. A. Hyde's United States patent No. 91,349, dated June

29, 1869, for dental pluggers, shows a piston fitted to reciprocate in a cylinder, in one end of which is fitted and held elastically a guided tool-holder and which the piston and connected ram strike, the reciprocating motion of the piston being produced by the rapid reciprocation of an air syringe or valveless single-acting pump, which, through a flexible tube alternately forces air into and withdraws it from the same cylinder, apertures being made in the cylinder below the ram to permit outside air to enter on the return stroke. In this device the speed is limited by the slow action of the air column in the elastic tube (*Figs. 17, 18*).

Geo. F. Green's United States patent, No. 88,290, dated March 30, 1869, shows the Bannister and Green device of 1867, improved by the severance of the tool-holder from the ram and the addition of a valve operated by the piston of the ram to work the double piston valve controlling the admission and exhaust of air to the ram cylinder (*Figs. 19, 20*).

Wm. Manson's United States patent, No. 152,391, dated June 23, 1874, shows a loose piston or ram worked by fluid pressure admitted above and below it in a cylinder having a tool-holder at its lower end. There is no returning spring, and no valve or valve-working mechanism (*Figs. 21, 22*).

Geo. W. Nichols' United States patent, No. 158,863, January 19, 1875, shows a cylinder containing a heavy piston or ram operated by air forced into each end alternately by a pair of bellows, connected to the cylinder by flexible tubes and worked by a tilting treadle. In this device the tool-holder is formed in the end of the ram cylinder itself and the entire cylinder, as well as the tool, partakes of the percussive action of the ram; the action of this device was therefore slow (*Fig. 23, 24*).

Geo. H. Reynolds' United States patent, No. 162,419, dated April 20, 1875, for a rock drill, shows a long piston working in a cylinder and operating an attached drill-holder; the piston in this device acts as a valve alternately to cover and uncover ports leading to the cylinder, and controlling the admission and exhaust. This in its functions resembles the valvular structure contained in MacCoy's cylinder, but is, from its construction, of slow and heavy operation, the

tool-holder being attached to the piston, and therefore incapable of as accurate guidance, or as quick reciprocation. It is here referred to only as an illustration of the valve-operating device (*Figs. 25, 26*).

S. W. Dennis' United States patent, No. 195,102, dated September 11, 1877, has a cylinder provided with grooves and ports, like MacCoy's, but instead of a cylindrical piston valve, a rectangular sliding valve in the piston (*Figs. 27–37*).

In I. M. Stebbins' United States patent, No. 203,667, dated May 14, 1878, the invention described in Hyde's United States patent, No. 91,849 of 1869, already referred to, reappears with a mere change of proportion of parts (*Fig. 38*).

Moreau and Dennis' United States patent, No. 205,289, dated June 25, 1878, shows the same invention substantially as Dennis' patent, No. 195,102 of 1877, already referred to, with two sliding valves in the piston, and corresponding grooves and ports in the working cylinder (*Figs. 39–49*).

S. W. Dennis' United States patent, No. 205,619, dated July 2, 1878, shows the same device substantially as his earlier patent, No. 195,102 of 1877, with the substitution of a cylindrical piston valve, like MacCoy's, for the rectangular sliding valve (*Figs. 50–60*).

Wm. H. Dibbles' patent, No. 211,652, dated January 28, 1879, shows a cylinder similar to Hyde's 1869 patent, with the exception that the holes beneath the piston are closed, and the piston is reciprocated by alternately exhausting and admitting air above it (*Figs. 61–64*).

W. Richman's United States patent, No. 213,134, dated March 11, 1879, for a dental plugger, shows the piston or ram working in a cylinder, with a valve and valve-seat, like Dennis' United States patent, No. 205,619, dated July 2, 1878, but placed lengthwise in the axial line of the piston (*Fig. 65*).

Beach and Arnold's United States patent, No. 245,433, dated August 9, 1881, shows a steam mining drill, in which a double-acting ram or piston operates a tool-holder, retracted by a helical spring, but without any provision for cushioning a recoil (*Figs. 66, 67*).

The patent of Samuel W. Dennis, No. 205,619, dated July 2, 1878, essentially anticipates that of MacCoy, and

possesses most of its features and capabilities, but had for its object to provide a motor or instrument for dental use only, while the invention of MacCoy consists in so perfecting the details, and proportioning the parts as to render possible the use of the tool in various arts and for numerous purposes already mentioned, which had not been dreamed of by previous patentees. The novelty does not lie in the mechanical functions of the tool, but in the perfection of its details and proportions, and particularly worthy of recognition is his bold conception of its possible applications, and the persistent efforts by which these applications have been successfully made.

The real nature of MacCoy's invention is well expressed in the following quotations from his patent No. 373,476, November 22, 1887:

"After the purchase of, and three years' costly experiments with, other patents most like the foregoing, together with my own inventing, I finally attained success mainly by securing an unprecedentedly high rate of speed (estimated as high as 15,000 strokes per minute) which could not be made by former machines and which unexpectedly permits the use of thinner-edged tools than could be used heretofore. These ends have been secured mainly by so changing the proportions and adjustments of the valve and parts as to give the striker a very short and an exceedingly rapid stroke and by making the striker and its metallic cylinder with an appreciable difference in their diameters, thus forming an air chamber around the striker, whereby an enormously rapid practically continous action is attained.

"No one has ever before planed marble or metal with a stroke machine so far as I can learn. The successive strokes of the bit or tool are so very rapid that there is not time between them for the tool to rebound or quit contact with the material; and furthermore when each stroke does work, and thereby imparts mechanical energy, the tendency or ability to rebound has departed from the tool with that energy, and the tool thus makes a practically continous progressive movement and planes the material, a

result not accomplished by any machine heretofore patented or constructed."

The invention is expressed tersely and aptly in the claim:

"The method of making a smooth surface on stone, metal or other hard substance by means of a reciprocating stroke machine, whose action is so rapid as to be practically continuous."

In conclusion, your committee deem the invention deserving the award of the John Scott Legacy Premium and Medal and respectfully recommend the same.

[Signed] LUTHER L. CHENEY,

Chairman Sub-Committee.

C. CHABOT,

N. H. EDGERTON,

JOHN HALL,

WM. C. HEAD,

ELI T. STARR,

WM. H. THORNE,

S. LLOYD WIEGAND.

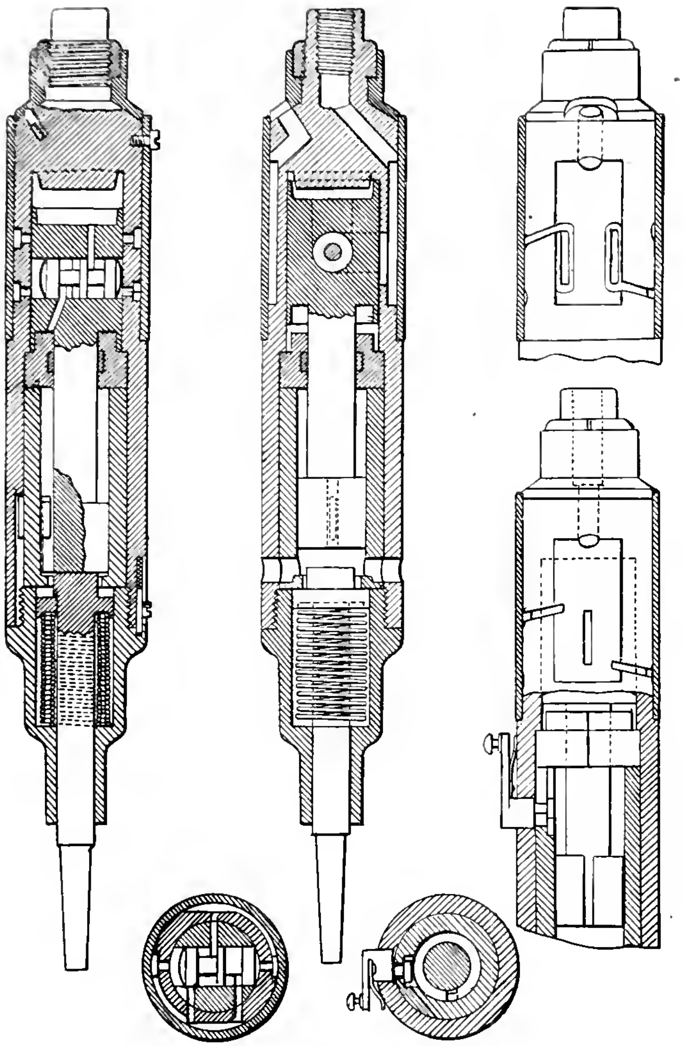
Adopted, June 5, 1889.

[Signed] S. LLOYD WIEGAND,

Chairman of the Committee on Science and the Arts.

17. E.

ti



FIGS. 1–6. James MacCoy's Pneumatic Tool.

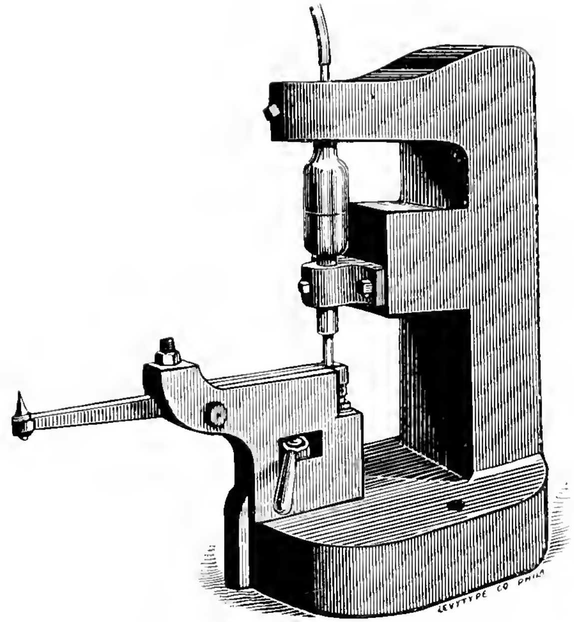
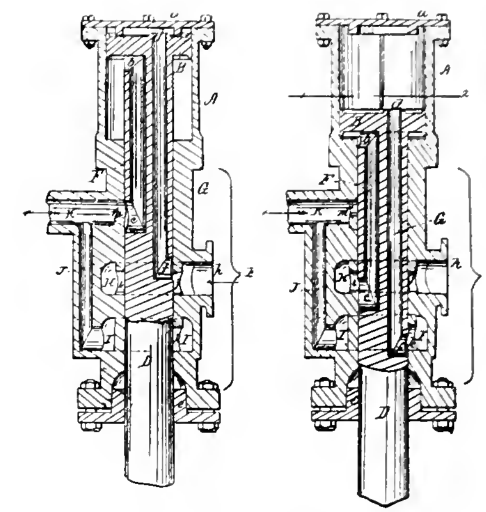
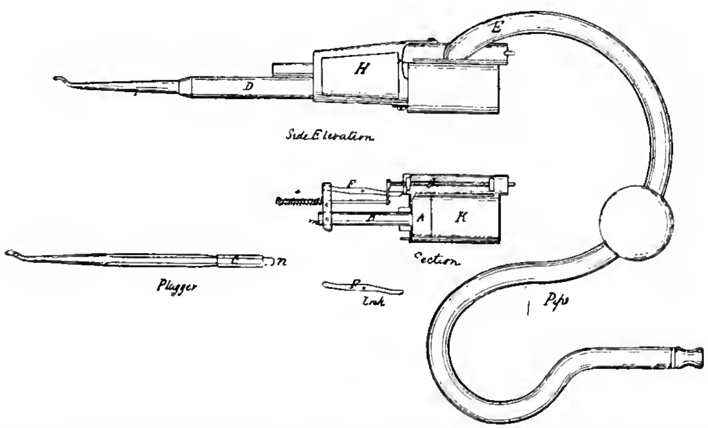


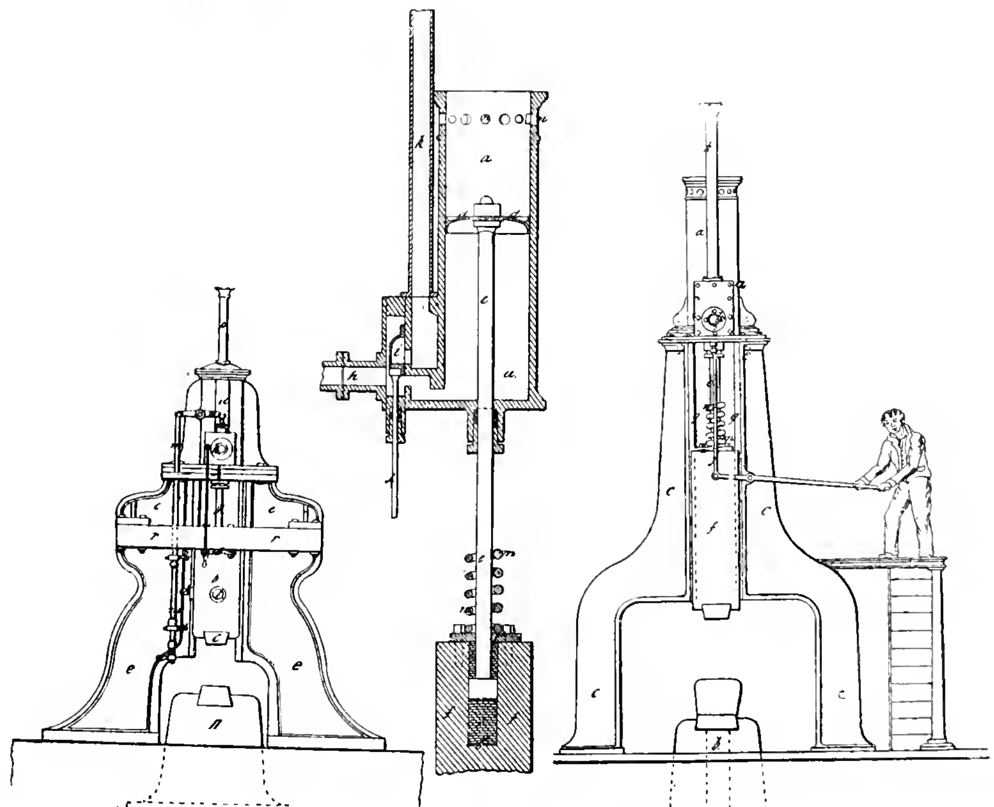
FIG. 7. James MacCoy's Repoussé Machine.



FIGS. 15, 16. David Joy (No. 80,550), 1868.



FIGS. 11–14. Bannister and Green (No. 71,950), 1867.



FIGS. 8, 9, 10. James Nasmyth (B. P. No. 3,042), 1843.

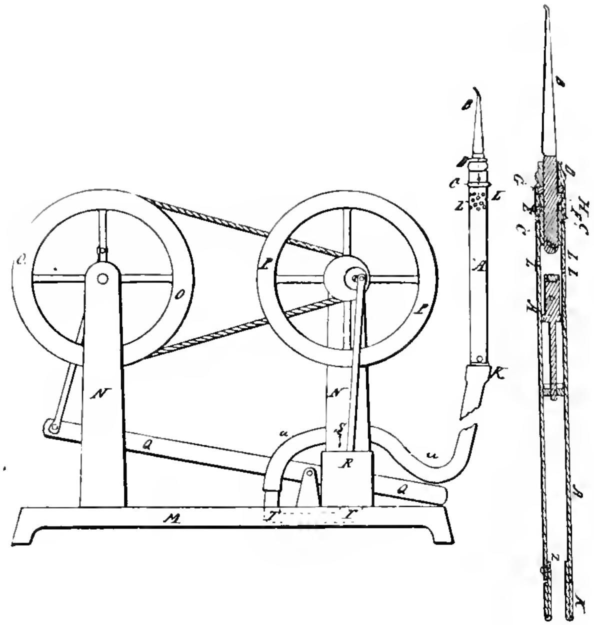
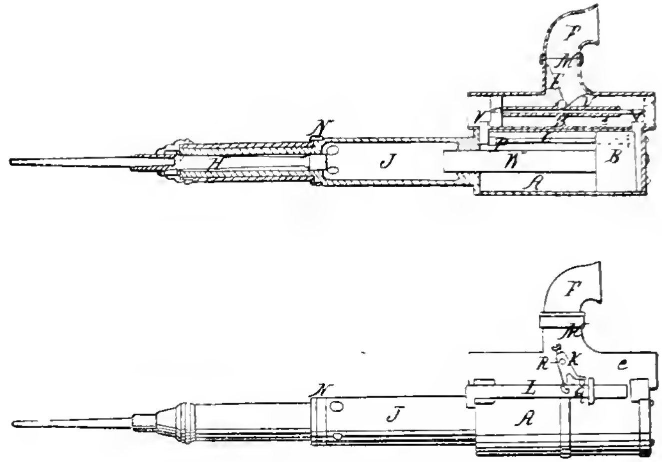
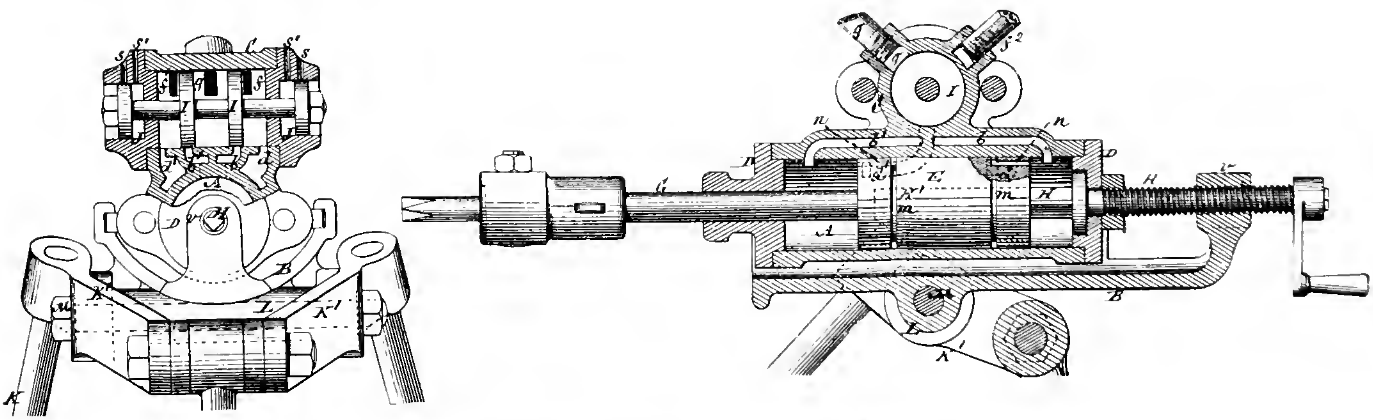


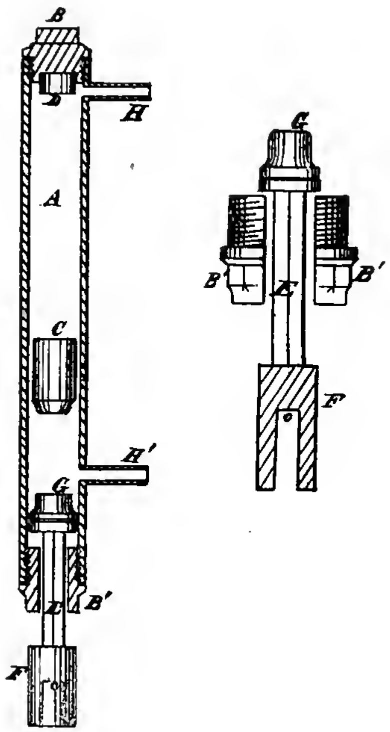
FIG. 17. E. A. Hyde (No. 91,849), 1869.



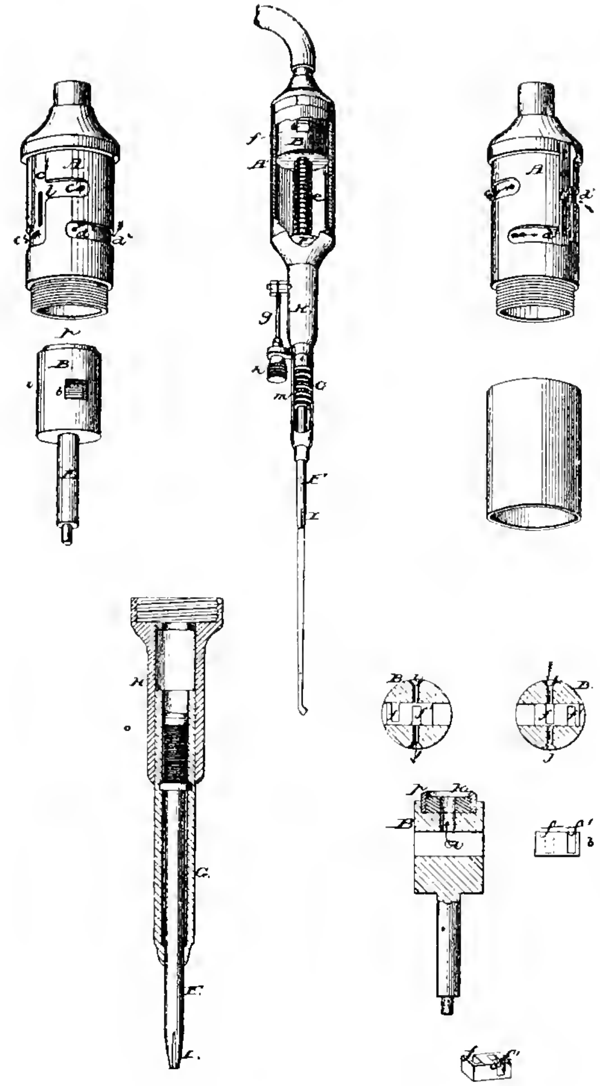
FIGS. 19, 20. Geo. F. Green (No. 88,290), 1869.



FIGS. 25, 26. Geo. H. Reynolds (No. 162,419), 1875.



FIGS. 21, 22. Wm. Manson (No. 152,391), 1874.



FIGS. 27–37. S. W. Dennis (No. 195,102), 1877.

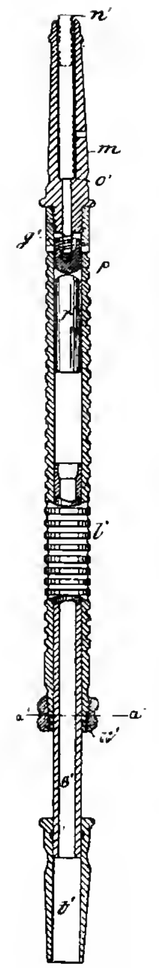
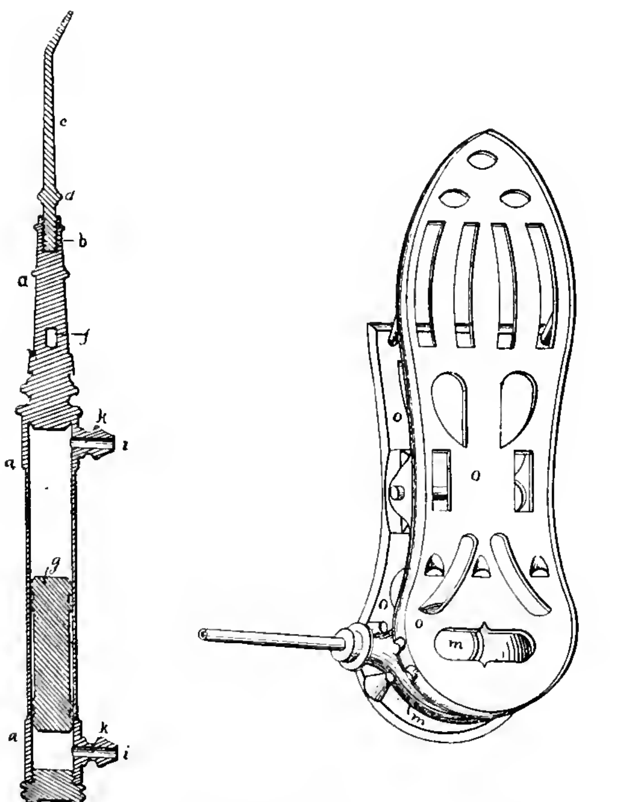
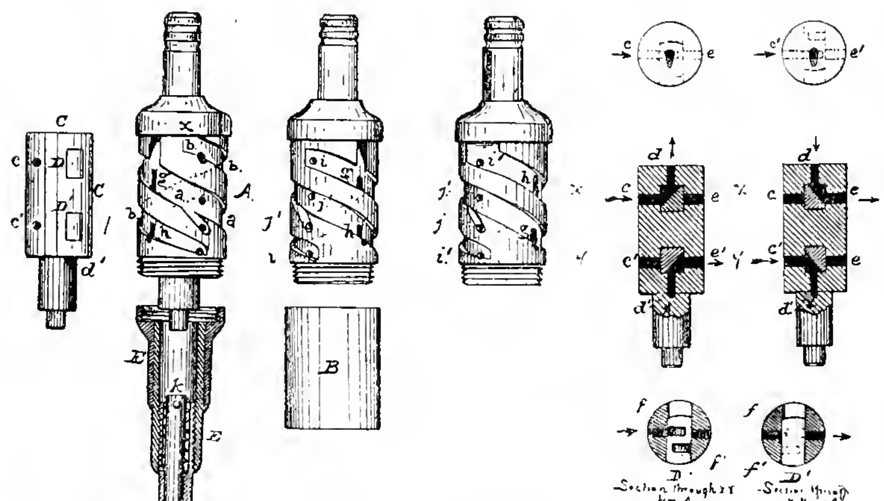


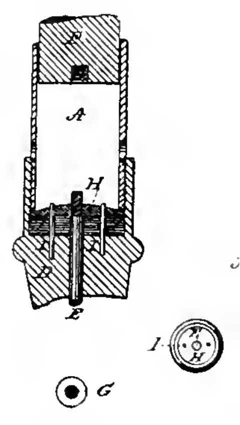
FIG. 38. I. M. Stebbins (No. 203,667), 1878.



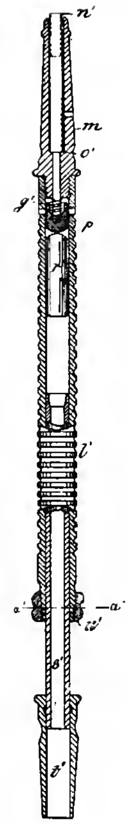
FIGS. 23, 24. G. W. Nichols (No. 158,863), 1875.



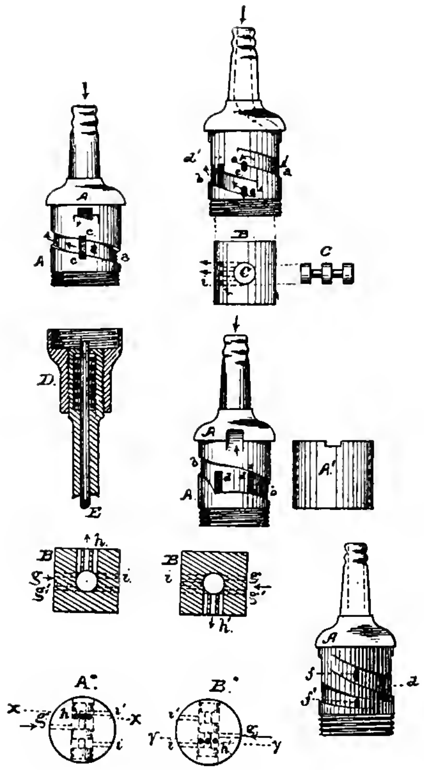
FIGS. 39–49. Moreau and Dennis (No. 205,289), 1878.



FIGS. 61–64. W. H. Dibbles



I. Stebbins (No. 203,667), 1878.



FIGS. 50–60. S. W. Dennis (No. 205,619), 1878.

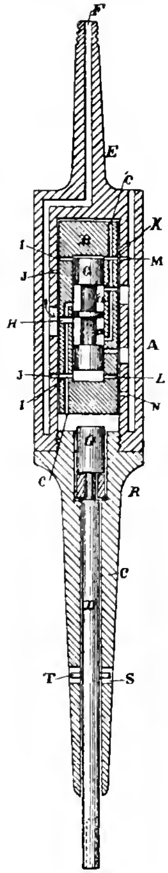
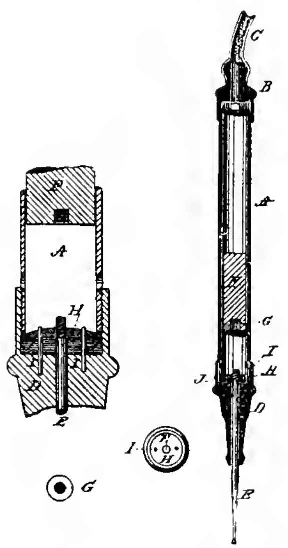
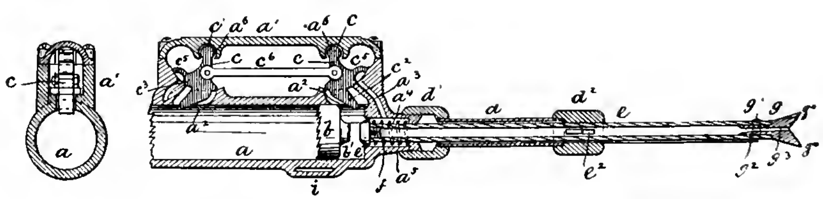


FIG. 65. W. Richman (No. 213,134), 1879.



FIGS. 61–64. W. H. Dibbles (No. 211,652), 1879.



FIGS. 66, 67. Beach and Arnold (No. 245,433), 1881.

BLINDNESS AND THE BLIND.

By L. Webster Fox, M.D.

[*A lecture delivered before the* Franklin Institute, *February 25, 1889.*]

(*Concluded from vol. cxxvii, page 437.*)

The second condition of defective vision and that which Americans should be careful to guard against, and yet are almost criminal in neglecting, is *myopia*, or *near-sightedness*. Civilization seems to be responsible for this increasing malady. Let any number of savages be tested for distant vision and mark the result—perfect vision. Transfer your examinations among the highest class of intelligence, or the book-worms and note the change—near-sightedness. Sift the statistics of Cohn, Risley and Darby. They tell us that myopia is rapidy on the increase among school-children. This means that as generation follows generation visual defects will also multiply. When Dr. Cohn, of Breslau, examined the eyes of 10,000 children, 1,000 were near-sighted. He found also, what was more important, that the number increased, as he ascended the schools from the primary to the higher classes. Bad light, badly constructed desks, both agencies being alike in causing children to stoop over their work. Then again, ten hours a day is much too long for a growing boy or girl to be harnessed to such close work. A director in one of the public schools recently brought his daughter to me to be examined for defective vision. I found that the child had so many lessons to write and commit to memory that she had two sets of books, one set remaining at home, the second set at school. The aggregate number of books were so many that she was unable to carry them. When school directors permit such a state of affairs, nature must succumb under the strain. Extreme cases of near-sightedness are always in danger of becoming blind by excessive eye strain; the inner coats of the eye separating and floating about in the vitreous fluids. Parents and teachers have a great responsibility resting upon them. They should see that children have proper glasses and should never allow them to assume

cramped positions, as stooping forward fills the blood vessels, and long continuance of this brings about changes which are hurtful to vision. Reading by moonlight, or defective artificial light, or in railway cars, is also a great source of evil. The pleasure a near-sighted person first experiences when using the proper glasses, is beyond description. I remember an instance of a general, who, during our late civil war, acquired a reputation for bravery in the field of battle far beyond what he deserved, as he expressed it years afterwards when he had his near-sightedness corrected by glasses. He found that his bravery was due to defective vision, not being able to see danger. Myopia was the making of his reputation, although many lives were lost, for no doubt he frequently led his men into danger, where, had he had good vision, he would never have ventured.

Having now explained the condition of visual defects brought about by either too short or too long measurements of the eyeball, I must dwell briefly on that condition of the eye where but one meridian is affected. It seems that this affection is more pronounced in the American type than in other nationalities. Not that it does not exist abroad, but our oculists probably are keener in its detection. I mean astigmatism. This defect may be far-sightedness or near-sightedness, or a combination of both. It comes from an eye whose focusing power is less in one meridian than in the other, or the curvature of the cornea is different in the two meridians. It is probably the source of more headaches than all the other visual defects combined. In looking at a card upon which radiating lines diverge from a point, its first and most obvious effect is to produce differences. Some may be perfectly clear and those at right angles blurred. In reading or drawing, one suffering with such a defect soon exhausts his vision.

Dr. R. B. Carter relates an anecdote of a gentleman suffering from astigmatism, or from what the patient described as, "periodical obscuration of vision." Dr. Carter found that the gentleman sat in an office which commanded a view of a large clock dial on the other side of a quadrangle. When the hands of the clock were approximately

vertical, he would see them plainly, but when they were approximately horizontal he could scarcely see them at all. The patient naturally thought he was a "curious physiological phenomenon." Glasses corrected the defect. Many students of Hebrew labor under this gentleman's mistake, the Hebrew characters being more pronounced in their horizontal lines. A clergyman once came under my notice who could not see lines running in a horizontal meridian. He was obliged to give up the study of Hebrew while a student at college. I have often been struck by the thought that probably the astigmatic eye might be held responsible for the peculiar formation of the letters of the different alphabets. If we examine the Hebrew type we find the horizontal lines much broader, while the German type is broader in the vertical. The Roman and Greek alphabets must have been invented by individuals with almost perfect vision, for these letters are the same in their different meridians.

Policemen and candidates for the fire department are subjected to a thorough physical examination at the hands of police surgeon Dr. T. H. Andrews. It falls to my province to examine them for defective vision and color-blindness. The examination of at least one thousand men show the defects of vision and lack of color sense to be exceedingly high. It is with pride that I can record the unwritten history of the good and efficient work done in this matter by our city officials. Men who readily pass an examination by daylight, might still have a defect which would render them incapable of doing duty at night. I may mention the case of one man, who held an appointment of trust, whose vision was good for his daily duties, but as soon as the twilight came on was so blind that he became helpless. This disease extended to sixteen members of his family, the result of a consanguineous marriage. How could such a man detect a burglar or the beginning of a fire in which hundreds of thousands of dollars might be lost? We now know the importance of having our "guardians of the night" equipped with perfect vision. This defect of night blindness, or nyctalopia, shows itself in two ways,

first by dimness of vision at night, and second by contraction of the field of vision, *i. e.*, an object which could be seen in the normal eye at the extreme right or left, the eye looking forward, would have to be brought to the front, approaching the middle line. A patient once graphically expressed the condition by saying that her eyes seemed to be gradually growing smaller.

Cataract is less clearly understood by the laity than almost any of the common affections of the eye. One invariably hears it described by individuals as a skin covering the sight. As the human being advances in years, we find the tissues contain less fluid, that the finger-nails, cartilages and bones become more mineralized, and so with the crystalline lens of the eye; it also takes upon itself a change. This change assumes a hardening and a consequent loss of transparency. As the lens is placed directly over the visual line, sufficient light cannot pass through the pupil, and the result is blindness. A certain amount is able to pass through an opaque lens. The light from a candle may be readily distinguished. When this is not so we find that the other parts of the eye have lost their functions, and in such a case it would be useless to remove a cataract. The oncoming of age is not always responsible for the development of cataract. Some are congenital, others the result of the abuse of health, and again traumatism enters largely into their development. Men who are engaged in furnaces, watching the molten metal and not protecting their vision with proper glasses, are extremely liable to early cataract. As to the exact cause of senile cataract we are still in doubt. Why one man at forty should have a thoroughly ripe cataract, and another man at seventy should escape, pathology leaves us in doubt. The predisposition to cataract before the age of forty is small, after this period relatively common. The habits of a people have much to do with its development. In countries where much cheap wine is drank cataracts are common. Professor Mooren, of Düsseldorf, once said to me that we, in the United States, would never have a large number of cataracts until our people drank more wine. Opium smok-

ing is said to produce cataracts. It is a well-known fact that cataracts are common among the Turks. Statistics fail to give us any information in regard to the Mongolians. Children are born with them, but fortunately nature takes a little compassion on her unfortunates, and instead of causing the whole lens to become opaque, the nucleus is the part affected. When dilating an iris which covers such a lens, a certain amount of vision is gained, but the peripheral part of the retina is only stimulated and vision is very imperfect. In such cases we have a constant rolling of the eyeballs, as if the person were constantly trying to get better vision. I have at present under my care a young woman who had this congenital defect. A needle operation was performed, the cataract was totally absorbed, but, contrary to my expectations, she still uses the peripheral part of her retina to see objects, the macula, or that part of the normal eye which is the sensitive part, being disregarded. Five years ago, at the Germantown Hospital, I had brought to my attention a case of congenital cataract, in a colored woman about sixty years of age. This woman had been blind from birth. She was able to see light but not form. After the successful removal of a cataract from one eye and the bandages were removed, for the first time in her life she looked upon the earth. She was quite nervous, and was afraid to walk. She was not able to measure distance, and would reach after objects a long way off. After assuring her that she could walk, she was led to the window to look upon the trees and the outer world. A flock of sparrows excited her very much, and when told that they were birds would not believe it. In walking she had no conception of distance, and would walk against objects in her way. Bright colors pleased her. When she wished to know the name of anything, she closed her eyes and felt the object with her hands. She was then able to tell what it was. About a year afterwards I removed the second cataract, which was also successful, and to-day she is still in the hospital as an employé, and is able to perform her duties as a general servant. It is not my purpose to enter into a detailed account of the various operations devised for the

removal of an opaque crystalline lens. That would be a subject which would probably interest medical students or members of the profession only. History has noted the fact that the ancient Egyptians recognized this form of blindness and performed an operation. Celsus described and practiced the needle operation, which operation was the only one performed for nearly 1,700 years. Daviel, a French surgeon, devised the corneal incision about the beginning of the eighteenth century, although it seems probable that the Arabians were acquainted with this method long before. As ophthalmic science advanced, various forms of operations were suggested and carried out. Fashions, in operations, run in grooves, just as we see it on the fashion plates. A particularly dexterous surgeon will find that he is successful in one kind of operation. He may have a large following of students, these students will imitate their teacher, and so it is that certain operations are introduced and become popular. To-day the ophthalmic surgeon has again attempted the operation without removing a part of the iris. This operation will in time be superseded by another, as time rolls on. Since the discovery of cocaine, much dread of the removal of cataracts has been taken away. This drug, which was discovered partly by accident, has been one of the best adjuncts to ophthalmic science.

The eye is an index to health. Note the change upon that man or woman who has lost much sleep either by press of work, disease, or mental worriment. There you will always see the opaque, glassy eye, lacking expression, showing more than in any other way that nature is exhausted. To the trained and observing physician the eye is an index to the seriousness of a malady more potent than the pulse or respiration. Since the introduction of the ophthalmoscope many diseases of the nervous system, of the circulation, and brain, are detected in their incipiency. By the examination of the background of an eye, at times with an equal degree of certainty the expert can prognosticate the lease of life. Watch the change in that individual who seeks early repose, takes plenty of out-door exercise, is guarded in his diet, spurns alcohol, tobacco, and other

stimulants. Let the face be ever so inattractive that eye, with its marvellous clearness, will attract our attention. Who has ever seen an intelligent man or woman with an eye that did not reflect the polish of the brain. Take the wretch, hardened to all the finer feelings which might once have existed in his organization, long steeped in crime and infamy. Note the difference. When such dull eyes of intensely passionate natures are looked at, you see the "eyes of born devils in human shape." The man whose brain has been ravished by disease and has become insane has the wild weird look that only a Poe could describe. There are some individuals, when under excitement, whose eyes reflect the activity of their brain like a "flash of light on a rocky coast." It is said that the eyes of Gladstone, when in the midst of a grand oration, will assume a most unnatural brilliancy, light will almost flash from them. Rossi and Irving seem to have stored away in their eyes electrodes, which emit sparks of light when overcharged with nervous excitement.

One is frequently asked, which eye is the stronger, the gray or the black? You might ask with an equal degree of propriety, which class of individuals are the longer lived, the blonde or the brunette. Color does not seem to enter into the strength of the eye. Nature in her wisdom had to guard the delicate organization of the eye by throwing around it a coat of pigment which absorbed an excess of light, hence it is that the race of people living in the torrid zone are dark-eyed and dark-skinned, while those living in the temperate zones, or where the rays of light are not so intense, have less pigment.

As I stated in the early part of my lecture, it is the abuse of the sense of sight which leads to weakness. This law holds good to the gray or black eye. In speaking of the beauty of eyes, a recent writer's views are as follows: "The most beautiful eyes in the world are the clear gray, with large pupils, and iris which changes and darkens with feeling as from the shadow of a cloud. The steadiness, brilliance and susceptibility of such eyes are an index to the rarest intelligence, quick and acute, and the high

romantic sentiments in which sôme characters become passions. Truth, liberality, loyalty, are the vital breath of such spirits, but, alas, those eyes are not of the long-lived. Dust is over them before we can say we have known them for our own."

The eye as an index to character has been described by Paracelsus, in 1616, in the following words: "To come to the practical part and give proper signs, with some of their significations, it is to be remarked that blackness in the eye denotes health, a firm mind, not wavering and fearful, but courageous, true and honorable. Gray eyes generally denote deceit, instability and indecision. Short sight denotes an able projector, crafty and intriguing in action. A squinting or false sight, which sees on both sides, or over and under, certainly denotes a deceitful crafty person, not easily deceived, mistrustful, and not always to be trusted; one who avoids labor when he can, willingly indulges in idleness, plays usury and pilfering. Small, deep-sunken eyes, are bold in opposition, not discouraged, intriguing and active in wickedness, capable of suffering much. Large eyes denotes a covetous, greedy man, especially when prominent. Eyes in continual motion signify short or weak sight, fear and care. The winking eye denotes a loving disposition, foresight, quickness in projecting. The downcast eye shows shame and modesty. Bright eyes, slow of motion, speak the hero, great acts, one who is daring and feared by his enemies, yet cheerful and sociable."

The best preservative to eyesight is out-door exercise. Watch the lustre of the eyes of that young man or woman who has just had a gallop through the Park, or who has had an hour at lawn tennis. A cold bath every morning stimulates the circulation, and with an active bounding of the blood through the arteries assimilation and elimination brings about good results. Heated rooms, with poor illumination, is a very prolific source of weak eyes. Reading or writing with the light falling on the page and reflecting its rays into the eyes often brings about a spasm of the little muscles which govern the accommodation and the

result is to exhaust the eyes. The light should always come from behind the individual and fall obliquely over the left shoulder. People who indulge in over-feeding, are careless about clothing, travel with damp feet, or dine irregularly, all suffer sooner or later from defective vision. A habit quite common among fashionable ladies, to whom nature has denied a black or brown eye, is to seek the secrets of the chemist's shop and apply a weak solution of belladonna or homatropine to dilate the pupil and render the cornea more brilliant. Even the cologne bottle has been drained of its contents to give brilliancy to the eyes. Such habits are only to be spoken of to be condemned. Let the natural lubricant be the only cosmetic used. See that the tears are kept healthy by proper means and nature will then do her duty. Another source of injury to the eye-sight is the indiscriminate use of glasses. Scarcely a day passes but the ophthalmic surgeon must pass judgment on from one to half-a-dozen pair of glasses which are shown him by his patients who have been allured to the shops of the enterprising opticians by the deceiving advertisement, "Eyes examined free," as if sight could be measured, as the cloth merchant deals with his goods—by the yard. The druggist who dispenses his drugs must be a qualified man. Is it less important that the man who deals with the most important sense should be less so? As the druggist is not a physician, so should the optician not pretend, by his practice, to be an oculist. I am sure that the note-book of every oculist is filled with cases showing where irreparable injury has been done by glasses improperly adjusted. I remember the case of a little girl who for several years was obliged by an over-zealous mother to wear glasses which were given her by an itinerant peddler for near-sightedness, when upon examination the child was found to be far-sighted. Many elderly people make a very grave mistake in submitting the care of their eyes to the same class of individuals.

When glasses must be changed more than once a year and the wearer is more than fifty years of age, there must be something wrong with the functions of the eye, and

while it may be only a signal of danger, yet that person should seek advice through the proper source. If ophthalmology is a science, then the making and prescribing of glasses are as different as the mixing and prescribing of drugs. We have before our Legislature a bill for the higher education of medical students. What a benefit would be conferred upon the community at large if a clause were added to that bill making it a misdemeanor to sell glasses without a prescription. The adjustment of glasses is a science as much dependent upon a scientific knowledge of the eye as the prescribing of drugs for symptoms which may be the forerunner of a serious malady. Within the last week I had to inform a young woman that she was hopelessly blind and that treatment would be of no avail. She had an affection of the optic nerve which, when it first made its appearance, caused dimness of vision. Thinking that a pair of glasses would remedy her failing sight, she sought aid at the hands of an optician who examined eyes free. She bought four pairs of glasses in as many months, receiving the assurance that it was only stronger glasses that she required. The law permits such wrongs, but the life of that young woman is condemned to utter darkness while life remains. In justice to some of our leading opticians I must say that they are exceedingly careful to whom and for what purpose they sell their wares. They may lose the sale of a dozen pairs of glasses, but what is that to the consciousness of knowing that they do not steal away the vision of individuals who, from their indigent circumstances, are the most to excite our sympathies. The Americans use their eyes as they do their brains and bodies. They condense as much labor into two score years as they should into three score and ten. Watch that boy going to school with a pack of books, whose weight has curved his spine before he has arrived at his fifteenth mile-stone. His eyes at this period of his life are overstrained, the result is, glasses must be brought into use to support a weakened condition of the muscles of accommodation. He grows into manhood weakened physically. Many men and women abuse the gifts given them by a prudent ancestry, by read-

ing through a forty column newspaper on a jolting railway train, or in a poorly-lighted street car, changing the focusing power with every foot of ground travelled. Our American journals, not content with giving a man a fair amount of reading for six days, double the dose on Sundays. The overworked business man needs as much rest for his eyes and brain, as the overworked laboring man for his muscles. The latter will prudently observe this one day. The business man must have his newspaper which, with its thirty pages of printed matter, must be read. Thus from Monday morning 'till Monday following his eyes and brain are kept constantly employed. This high pressure is going to show its effects sooner or later. Were it not for the new blood brought into our country by the peasants of Europe, which prevents our race from degenerating, I would not like to answer the question as to what would become of us as a race in a few generations. Education must be given to children, the fine arts cultivated, business must go on, but let us halt and think. We owe something to posterity. The greatest inheritance a child can have is a good physique, which also means good health. The care of the eyes in childhood is of the greatest importance. They are more sensitive to light then than in adult life. A mother or nurse will frequently expose the eyes of an infant to the glare of the sun for hours at a time. One can surmise the evil which will be the outgrowth of such carelessness. The greater number of the blind lose their sight from carelessness during infancy. When one visits a blind asylum and sees the number of children who could have been saved from their deplorable condition, one grows heartsick. Parents must remember that, as the child advances in years, a difference may exist in its eyes. As the child is father to the man, so do oculists know that the eyes in childhood are subject to as much variation in their power of seeing as in adult life. The eyeball of one child may be normal, in another either too short or too long. A variation from the normal means eye strain.

It has been found that near-sightedness largely exceeds far-sightedness of children in cities. We speak against the

early instruction of children. Seven to nine years of age is soon enough for children to begin their studies. By this time nature has acquired a certain development which can resist to some extent the amount of labor put upon an eye. Children should have good light during their study hours, and should not be allowed to study much by artificial light before the age of ten. Books printed in small type should never be allowed in school-rooms, much less be read by insufficient light. The selection of occupation for children should not be neglected. Examination for color-blindness should be gone into, visual defects searched out. How very unfortunate it would be for a boy who had given a certain amount of his student life to the study of an occupation which he could not follow. A boy might be able to see the time on the steeple of a tower half a mile away, yet not be able to follow a line in drawing for five minutes. An out-of-doors occupation in such a case might make him a successful man, while he would fail as an architect, no matter what his ability as an artist might be.

The eyes of the adult may suffer from any cause. Overwork, with insufficient light, is a prolific cause of trouble. Dr. Carter tells us that natural light is as necessary to the eye as food to the stomach. At one time it was the fashion to have houses made as gloomy as dark paper on walls could make rooms. Dark blinds, guarded by shutters painted in some dark color. When people so housed come forth into the natural light they remind one of a squinting race. All of this was a prolific source of eye trouble.

Writers on hygiene have the satisfaction of knowing that their condemnation is producing different effects in home decoration.

To those who are familiar with Beethoven's beautiful, and world famous "Moonlight Sonata," it must be a pleasure to know that it was inspired by a blind girl. The story is told by a friend of his, who accompanied him one evening on a walk through a narrow street in Bonn. While they were passing the door of a cobbler's shop, Beethoven suddenly stopped, and as his ear detected the sound of music said, "Hark, what sound is that? It is from my sonata in

F. How well it is played." They entered the room and found seated at the piano a blind girl, her brother near by repairing shoes. "Pardon me," said Beethoven, "but I heard music and was tempted to enter. I am a musician. I overheard something of what you said. You wish to hear some good—that is—shall I play for you?" There was something so odd in the whole affair, and something so comical in the manner of the speaker, that the spell was broken in a moment, and all smiled involuntarily. "Thank you," said the shoemaker; "but our piano is so wretched, and we have no music." "No music," echoed my friend; "how, then does the young lady—" He paused and colored, for as he looked in the girl's eyes he saw that she was blind. "I, I entreat your pardon," he stammered; "I had not perceived before. Then you play by ear?" "Yes," said the girl; "we lived at Bruhl for two years, and while there I used to hear a lady practicing near us. During the summer evenings the windows were open, and I walked to and fro outside to listen to her." She seemed so shy that Beethoven said no more to her, but seated himself quietly at the piano and began to play. He no sooner struck the first chord than I knew what would follow, how grand he would be that night. And I was not mistaken. Never during all the years I knew him did I hear him play as he played to that blind girl and her brother. He seemed to be inspired; and, from the instant when his fingers began to wander along the keys, the very tone of the instrument seemed to grow sweeter and more equal. The brother and sister were silent with wonder and rapture. The former laid aside his work; the latter, with her head bent slightly forward, and her hands pressed lightly over her breast, crouched down near the piano, as if fearful lest the beating of her heart should break the flow of those magical, sweet sounds. It was as if we were all bound in a strange dream, and only feared to wake. Suddenly the flame of the single candle wavered, sank, and went out. Beethoven paused, and I threw open the shutters, admitting a flood of brilliant moonlight. The room was almost as light as before, the moon's rays falling straight upon the piano and player. But the chain of his ideas

seemed to have been broken by the accident. His head dropped upon his breast; his hands rested upon his knees; he seemed almost absorbed in thought. He remained thus for sometime. At length the young shoemaker rose and approached him eagerly, yet reverently. "Wonderful man," he said in a low tone; "who and what are you?" "Listen," said Beethoven, and he then played the opening bars of the Sonata in F. A cry of delight and recognition burst from them both, and they exclaimed, "Then you are Beethoven!" They covered his hands with tears and kisses. He rose to go, but they held him back with entreaties. "Play to us once more, only once more." He suffered himself to be led back to the piano. The moon shone brightly through the window and lighted up the glorious rugged head and massive figure. "I will improvise a sonata to the moonlight," he said, looking up thoughtfully to the sky and stars. Then his hands dropped upon the keys and he began playing a sad and infinitely lovely movement, which crept gently over the instrument like the calm flow of moonlight over the dark earth. This was followed by a wild, elfin passage in triple time—a sort of grotesque interlude, like the dance of spirits upon the lawn. Then came a swift *agitato finale*—a breathless, hurrying, trembling movement, descriptive of flight, and uncertainty, and vague impulsive terror, which carried us away on its rustling wings, and left us all in emotion and wonder. "Farewell to you," said Beethoven, pushing back his chair and turning toward the door—"farewell to you."

HARBOR BAR IMPROVEMENTS.

By L. M. Haupt, C.E.

That the prosperity of a nation is measured largely by and dependent upon its commerce is proven by the history of the maritime countries of the world. Probably the most renowned instance on record is to be found in the astonishing growth of the Venetians in wealth, power and influence. Located in an out-of-the-way corner of the Adriatic, and surrounded by a labyrinth of islands and lagoons, Venice rapidly expanded from her straw-thatched huts to her marble palaces, while her navy defied the world for well-nigh fourteen centuries.

The ocean is the highway of nations, and her gateways are the ports which indent her borders. Where these portals are spacious, safe and unobstructed, there will commerce thrive, and the greater the number of such gateways, the more fully will both internal and international comity be developed.

The Nicaragua Canal, like her oriental sister at Suez, will be a diadem in the girdle of the earth, binding the East and the West, the North and the South, more closely together by thousands of miles, and thus hastening the time when the civilization and influence of the great Anglo-American commercial nations shall pervade the world.

"Peace hath her victories no less renowned than war," and such victories as these are most potent factors in removing the *casus belli.*

It is a well-known fact, however, that the unceasing forces of nature, the winds, waves, tides, and currents, aided by gravity, have bolted these gates by bars which have taxed the ingenuity of man for centuries to unloose; for man and his works are finite, but the sea is the work of the Infinite, and His forces endure through ages. If the barriers may not be removed, at least in part, or a pathway be opened through them, then must commerce and the nations

languish. Hence the momentous importance of the problem and the justification for the expenditure of millions in the attempt to solve it.

In making this attempt, however, it would seem to be necessary that judicious regard be paid to the lessons of experience, and that past failures should not be repeated under similar conditions.

The old world is full of instructive precedents as to the operation of the various systems which have been tested for generations, and the new world seems bent upon repeating these extravagant experiments, only on a grander scale.

According to the highest official authority in the United States, the methods available for the treatment of these important works for harbors on alluvial coasts are but two in number, namely, "by dredging alone, or by using tidal scour between jetties, aided, if necessary, by dredging. As to the first method, it has already been tried unsuccessfully." As to the second, the same authority states: "The jetties should be so placed as to secure the greatest tidal scour practicable without seriously injuring the interior harbor, and without greatly endangering the safety of the jetties against undermining, or of Galvestown Island from overflow in great storms. The greatest scouring effect will be obtained, and the greatest security against undermining, by making the jetties tight and by raising them above high water."*

These latter conclusions were only reached after a score of years had been spent in experimentation, at a cost of $1,576,337.12, and the result to date has been no increase of depth over the bar, but a hastening of the anticipated evils, so that to-day the total estimated cost of this single project is $8,478,000. After so great an outlay and the lapse of the years required to complete this work, what result may be predicted? The authorities say, "Such a jettied channel offers more resistance to inflow than does the present entrance; reduces the present tidal prism about one-third; allows the bay to fill more slowly than the present entrance does and

**Ex. Doc.* No. 85. House of Representatives, Forty-ninth Congress, First Session. p. 13.

hence gives greater differences of level," and they add in closing their report, "The jetties will diminish the freedom of inflow at Galveston." In short they will violate the fundamental requirements of the greatest freedom of influx to the flood tide that there may be a full prism for the ebb scour, and yet with these admissions before them the people of the state of Texas, trusting to this forlorn hope, appeal urgently for the rapid completion of the project.

Is this the *dernier ressort* of the profession of engineering in this nineteenth century, and must we follow blindly the precedents of the middle ages, modified only by the materials of modern times? If so, there are few places, indeed, of sufficient importance as to justify the great expense required for annual dredging and maintenance.

The difficulties surrounding these questions, as seen by the Board of United States Engineers, are expressed in the following extracts from a report on one of the Texas passes:

"The problem of the improvement of the navigation of this pass is by no means an easy one. Some of the difficulties may be mentioned, viz., the want of stability in position of the pass itself; * * * the instability of the foundation on which any structure is to be built; the shifting sand of the Texas coast; the presence in the water in which any structure must be placed of the sea worm (teredo) in such activity that wood cannot be used except to a very limited and exceptional extent, if at all; the necessity of bringing stone, cement, etc., from long distances and at much expense; the heat and other discomforts of a tropical climate increasing the cost of labor." In suggesting a method of procedure the Board say, "The first step in the improvement is to adopt some means of checking the recession of the island which limits the pass on the western side. * * * As the work progresses experience will probably suggest variations of detail. There is a good prospect of success in deepening the channel by the use of two jetties. The locations for them, as recommended, are approved subject to such change as further study may show to be expedient."

Notwithstanding these exceptional difficulties the plan of jetties in pairs, founded upon brush mattresses, is adopted, yet the report bears inherent evidence of doubt as to method, location, material and results, in fact the day after signing it one of the most experienced officers of the Board writes: "I wish it to be understood that with the information now before me I believe one jetty *may* suffice at this locality." * * * "The views of (the officer in charge)* on the subject of the form in plan of jetties are clearly and strongly put, but I do not coincide in them entirely, either in general application or in particular at this locality."

The soundness of this opinion, which would reduce the cost of the work about one-half and increase the probability of securing deeper water, are based upon a few physical characteristics of this and other inlets. They are, the general direction of the resultant of the forces acting along this coast, which produces a gradual yet constant progression of the inlets to the south and west at the rate of about 200 feet per annum, and the flexure of the ebb channel, where it crosses the bar, in the same direction. These obstructions are not delta bars formed by the deposition of sediment from the interior drainage area, but are drift bars composed of beach sand rolled along by the waves and littoral currents, as affected by the incoming tides, and checked abreast of the opening through the outlying sandy cordon. The ebb currents being obstructed by the deposit are turned to the southward and effect their escape along the line of least resistance, which hugs the lee shore and has a direction nearly at right angles to that of the flood component.

Thus, the source from whence comes the sand forming the bar being known, the remedy would seem simple, and the first requirement would be to keep the sand out of the ebb channel by a suitable obstruction, which would not seriously oppose the free ingress of the tide.

The barrier must be placed between the source of supply and the channel. What must be thought then of a policy which invariably directs the construction *first* of the

* The writer has omitted names to avoid the appearance of personalities.

jetty on the farther side, where its effects are soon manifested by the large shoals created in the natural path of the ebb currents, and which they are obliged to roll on, if possible, into deeper water, thus pushing the bar seaward, adding to the ultimate cost, increasing the undermining of the work, and finally burying it under the original bottom? As well might a snow-fence be placed on the wrong side of a railroad cut to prevent it from filling with snow. These results are not idle speculations, but oft-repeated facts, proven by surveyors; for example, in a report on the jetty partially built upon the *south* side of one of the Texas inlets, the officer in charge says that "out of the total length of 5,253 feet of jetty constructed, about 775 feet, built upon shore, and constituting a root to the jetty rather than the jetty itself, has been well maintained; 1,710 feet has diminished in height from forty-seven to eighty-five per cent., and the remaining 2,768 feet (over half a mile) has practically disappeared. The trenches which have been formed at the sides of the portion of the work which remains, constitute a disadvantage in its further prosecution, which more than counterbalances the advantage of utilizing the material now in place. * * * It will be economy to abandon the present site and lay out a new line parallel with the present one and about 250 feet west of it." * * * "The lightness of the structure and the teredo are not sufficient to account for this. (The injury to the site.) Neither of these causes could have placed the mattresses where they are now found, below the original bottom and buried in the sand." * * * "It is possible, but not certain, that the work, when completed, will secure a depth of twelve feet over the bar." This experience cost $290,000 up to July 1, 1886, and it is estimated that the completed structures will foot up to $3,826,437.50.

All to secure a channel of possibly twelve feet depth while the natural depth varies from seven to thirteen feet. The proposition to rebuild 250 feet west of the former site would merely prove to be a repetition of the above experience.

At another of these inlets, where the normal depth varies

from seven to nine and one-half feet, and where $481,250 have been expended up to July 1, 1888, it is stated that "the effect of the work upon the bar has been insignificant." Here a jetty, having a total length of over a mile, was also built upon the south (the wrong) side of the pass, and was found to have settled over fifty per cent. along the outer half, while the northern jetty has not yet been begun for lack of funds. Had the jetty been built originally on the north side, and in proper form and position, the other would have been useless, and a marked improvement in the channel would have been the result.

This is shown by the temporary jetty constructed by private parties in 1869 at this pass at a cost of only $10,000. This jetty was but 600 feet long, and built of light, perishable materials, yet so long as it remained it increased to and maintained the depth in the channel at twelve feet, and as it was gradually broken up by the waves, the channel shoaled to its former condition.

Although this precedent was known to and reported upon by several of the engineer officers of this district, they failed to profit by the experience thus furnished. These works were, therefore, started wrong, and they have either wholly or partially disappeared.

Even in pursuance of the jetty system, it is admitted that "it is the history of all jetties that they will in time require extension. No plan should be followed which does not keep in view future extensions." * * * "If two jetties are to be built, they should be essentially parallel to each other." * * * And, again, "Whatever difference of opinion there may be as to how much depth will be secured by a single jetty, there can be none, I think, as to whether a greater depth will not be obtained by two."

Per contra, one of the highest English authorities in a comprehensive review of jetty harbors on the continent says: "The jetties also, in most cases, were extended in the hope of reaching deep water, which proved fruitless, owing to the progression of the foreshore with each extension of the jetties. Next, artificial sluicing basins were formed to provide a larger mass of water for sluicing, with the additional

advantage that the issuing current was nearer and better directed for scouring the entrance. Lastly, dredging with sand-pumps is being largely employed for deepening the channel beyond the jetties. The parallel system has not proved successful in providing a deep entrance without constant works. * * * Parallel jetty harbors are one of the most difficult class of harbors to design and maintain successfully. * * * Sluicing and dredging are the two means by which the entrance to these ports may be maintained and improved. They are both needed, as they possess distinct functions."*

Again, the President of the Institution of Civil Engineers, of Ireland, says: "The system so generally adopted in Continental ports, of parallel, or nearly parallel jetties, extending only to comparatively shallow depths, appears to be radically wrong in principle. Their tendency generally is to act as groins, and make the sandy shore extend outward until the sand passes around the pier-heads where the action of the sea heaps it up in the form of a bar."

Whilst there are a few instances of the success of parallel jetties, notably at the mouths of the Danube and the Mississippi, it will be observed that the bars at these points are delta-bars, that there is little or no tide, with no inner bays, and that, consequently, the ratio of tidal prism to fresh-water discharge is very small and by far the larger volume of flow is seaward. These conditions do not obtain where there are large interior bays or lagoons which must be filled at every tide to maintain the scour over the bar, and where every structure placed on the bar becomes more or less of an obstruction to the influx of the tide.

For this reason the dike proposed a few years since for the improvement of the entrance to New York Bay, and reaching from Coney Island in a south-southeast direction for about five miles towards Gedney's Channel, would, if built, have proven more injurious than beneficial. It was estimated to cost about $5,000,000.

The causes for the degradation of this most important entrance are the sands travelling northward along the

* *Harbors and Docks.* By Sir Vernon Harcourt, Oxford, 1885.

Jersey coast, and westward along the Long Island beach, with the flood tide. Thus the comparative surveys of Fire Island Inlet* show a westward progression of the shore line amounting to two miles in about fifty years. At Rockaway Inlet there is a similar movement, which is also observable at Norton's Point, the western extremity of Coney Island, but not to so great an extent, due to the eroding action of the ebb cross-currents from the upper bay.

On the other hand Sandy Hook has increased a mile and a quarter in length within the century, and the sands which are unceasingly transported to its extremity are now distributed by the ebb currents through the Main Ship Channel over the submerged banks surrounding Gedney's Channel. Under these conditions dredging can furnish but temporary relief, yet it may prove to be the most economical of the several methods available at this particular site. To effect a radical improvement here the encroachments of the beach sand must be arrested. Dikes or jetties in pairs, at this entrance, would be the worst possible expedient.

The commission of the Waterstaat of Holland say: "It is to the action of the tides mainly that the maintenance of the depth in our river mouths must be attributed. The total effect depends upon the *velocity* and *volume;* both increase with the tide-range, that is with the difference between high and low water. If these cannot be increased sufficiently to maintain a profile adequate to the needs of commerce, the end can only be attained by dredging or by a resort to artificial canals."

It is evident, therefore, that any dikes or jetties which would limit or interrupt the tidal oscillation would to that extent prove injurious to the channel, and the greater the tidal range the more serious do such obstructions become, yet the jetty system is the one which is almost universally resorted to as the only panacea for insufficient water over the bars.

Some idea of the magnitude of the works now in progress in this country may be obtained by a review of the expendi-

* See FRANKLIN INSTITUTE JOURNAL for April, 1889.

tures upon a few of our Atlantic and Gulf ports, as given in the accompanying exhibit.

Locality.	Cost to July 1, 1888.		Estimated to Complete.	
Aransas Pass, Tex.,	$481,250 00		$1,668,500	
Pass Cavallo, Tex.,	290,000 00		3,826,437	
Galveston, Tex.	1,825,278 63		6,752,721	
Sabine Pass, Tex.,	548,750 00	appropriation.	2,051,250	
Mobile, Ala.,	978 830 00	"	276,000	by dredging.
Pensacola, Fla.,	215,000 00	"	25,000	"
St Augustine, Fla.,			1,467,888	
Jacksonville, Fla.,	732,000 00		576,500	
Fernandina, Fla.,	3[illegible]6,782 64		1,592,023	
Brunswick, Ga.,	92,463 27		100 000	
Savannah, Ga.,	1,032,000 00		6,660,000	
Charleston, S. C.,	1,482,500 00		1,525,000	
Totals,	$7,984,854 74		$[illegible]6,521,319	

These works have been in progress for periods of from ten to twenty years, yet none of them are completed. At this rate of making appropriations it will require from thirty to sixty years to complete them, and there can be no question that the cost is greatly augmented by the scour induced by this temporizing method of doling out the funds.

In those cases where only one jetty has been started and that on the wrong side, no beneficial results are manifest. Where two have been built to high water, a slight but temporary improvement is noticeable, during the transition stage, as the crest of the bar is moving seaward and the groins are filling preparatory to the general advance of the foreshore. In these cases the main benefit is due to the protection afforded the ebb channel by that jetty which intercepts the sand movement. In the most prominent cases, as at Galveston and Charleston, there have been no important improvements in depth over the outer bars. At Pensacola and Mobile the improvement is due to dredging and is not permanent.

Thus far attention has been directed to the physical conditions surrounding the problem and space will not permit an expansion into the legislative or executive considerations. These have already been ably presented by experienced and competent economists, and it is therefore not a matter of surprise that at length the subject is

beginning to attract the attention of legislators who desire, in behalf of their constituents, to secure results more expeditiously by securing some changes in the methods of making appropriations and administering these public works.

To this end the Committee on Expenditures in the War Department, Mr. Laffoon, Chairman, in reporting favorably a bill for this purpose, say: "The time has come to inaugurate a definite policy in regard to national public works, and to provide a specific agency for its execution. The sense of the people and of Congress has shown a steady growth for twenty years in favor of the development of harbors and water-ways. During this time grave objections have been urged against legislative and administrative methods, and these objections have gathered force with each passing year. * * * In legislation, it is charged that Congress is not appropriating in harmony with any well-conceived general plan or system; that each work is largely considered as a detached or individual work, without special regard to any other or to any collection or group of works as a whole; that appropriations are uncertain and inadequate for economical results, and often for any results at all; and that the largest and most important national works fail to receive that attention which is indispensable if they are ever to be completed."

"In administration various objections are urged which are largely incidental to the necessary methods of organization of a military body, and that are not adapted to a strictly civil work and function. * * * A necessary, and the larger part of the technical force, is without proper recognition, tenure of position or hope of advancement, resulting in constant change in personnel, as some experience is acquired. The military system does not readily adapt itself to the best civil practice, nor is it desirable that it should if the corps is to remain a part of the army." * * * "The truth of these allegations, to a greater or less degree, is acknowledged by every one. They can be indefinitely multiplied and expanded and have been ably presented to your committee. Great good would come by changing the legislative prac-

tice, likewise by a specific adaptation of the administrative organization to its work."

The importance of such changes as are proposed becomes the more apparent when it is seen that the policy of present methods leads to a reduplication of the unsatisfactory Continental experiences, at great waste of time and expense, while the fundamental requirements of admitting the flood tide freely, defending the ebb channel from the encroachments of the beach sand, conserving the ebb discharge for scour over the bar and providing an ample water-way for navigation are very imperfectly fulfilled by the jetty system as at present applied.

CABLE TELEGRAPHY.

By Patrick Bernard Delany.

[*A lecture delivered before the* Franklin Institute, *Monday, March 11, 1889.*]

The Lecturer was introduced by Prof. Edwin J. Houston, of the Institute, and spoke as follows:

Mr. President, Ladies and Gentlemen:

When the Franklin Institute honored me with an invitation last summer to read a paper on a subject of my own choosing, I accepted on condition that the time be set a good way off, and selected "Cable Telegraphy" as my theme.

We are all apt to be prodigal of promises of remote fulfilment, but as the day of reckoning approaches, we sometimes pay the penalty of our rashness in misgivings of our ability to make our promises good. When I made the engagement I was greatly interested in an invention for cable telegraphy which I was then bringing out, and which I expected would lead to experimentation, and results satisfactory to myself and interesting to the Institute. Realizing as the time for my paper drew near, that my opportunities for experimentation had been very limited, owing

beginning to attract the attention of legislators who desire, in behalf of their constituents, to secure results more expeditiously by securing some changes in the methods of making appropriations and administering these public works.

To this end the Committee on Expenditures in the War Department, Mr. Laffoon, Chairman, in reporting favorably a bill for this purpose, say: "The time has come to inaugurate a definite policy in regard to national public works, and to provide a specific agency for its execution. The sense of the people and of Congress has shown a steady growth for twenty years in favor of the development of harbors and water-ways. During this time grave objections have been urged against legislative and administrative methods, and these objections have gathered force with each passing year. * * * In legislation, it is charged that Congress is not appropriating in harmony with any well-conceived general plan or system; that each work is largely considered as a detached or individual work, without special regard to any other or to any collection or group of works as a whole; that appropriations are uncertain and inadequate for economical results, and often for any results at all; and that the largest and most important national works fail to receive that attention which is indispensable if they are ever to be completed."

"In administration various objections are urged which are largely incidental to the necessary methods of organization of a military body, and that are not adapted to a strictly civil work and function. * * * A necessary, and the larger part of the technical force, is without proper recognition, tenure of position or hope of advancement, resulting in constant change in personnel, as some experience is acquired. The military system does not readily adapt itself to the best civil practice, nor is it desirable that it should if the corps is to remain a part of the army." * * * "The truth of these allegations, to a greater or less degree, is acknowledged by every one. They can be indefinitely multiplied and expanded and have been ably presented to your committee. Great good would come by changing the legislative prac-

tice, likewise by a specific adaptation of the administrative organization to its work."

The importance of such changes as are proposed becomes the more apparent when it is seen that the policy of present methods leads to a reduplication of the unsatisfactory Continental experiences, at great waste of time and expense, while the fundamental requirements of admitting the flood tide freely, defending the ebb channel from the encroachments of the beach sand, conserving the ebb discharge for scour over the bar and providing an ample water-way for navigation are very imperfectly fulfilled by the jetty system as at present applied.

CABLE TELEGRAPHY.

BY PATRICK BERNARD DELANY.

[*A lecture delivered before the* FRANKLIN INSTITUTE, *Monday, March 11, 1889.*]

The Lecturer was introduced by Prof. EDWIN J. HOUSTON, of the INSTITUTE, and spoke as follows:

MR. PRESIDENT, LADIES AND GENTLEMEN:

When the FRANKLIN INSTITUTE honored me with an invitation last summer to read a paper on a subject of my own choosing, I accepted on condition that the time be set a good way off, and selected "Cable Telegraphy" as my theme.

We are all apt to be prodigal of promises of remote fulfilment, but as the day of reckoning approaches, we sometimes pay the penalty of our rashness in misgivings of our ability to make our promises good. When I made the engagement I was greatly interested in an invention for cable telegraphy which I was then bringing out, and which I expected would lead to experimentation, and results satisfactory to myself and interesting to the INSTITUTE. Realizing as the time for my paper drew near, that my opportunities for experimentation had been very limited, owing

picked up, spliced and completed. There are now ten cables across the Atlantic, and their location and condition is about as well known by those who have to do with them as though they were exposed to view for the entire distance. It has been said of Captain Trott, the well-known cable fisherman, that he knows the mountains and valleys, lanes and avenues of the ocean as well as a cabman knows the streets of London. Crossing the Atlantic on one occasion with his repair steamer, and realizing that he was in the vicinity of the spot where a stretch of cable had been lost by another company's steamer some time previous, the captain set to work, picked up the cable within an hour or two, and delivered it to its owners on his arrival. Two of the Atlantic cables were grappled, hauled up and repaired in mid-ocean last summer. It is expensive work, sometimes costing two or three hundred thousand dollars.

There are now throughout the world over 116,000 miles of submarine cables, with nearly 125,000 miles of conductors. Only in short cables can more than one conductor be used. That is to say two wires, each insulated from the other, cannot be operated in long cables on account of a cross-fire known as *induction* between them. Hence, the mileage of cable is almost as great as the mileage of conductors. The Eastern Cable Company alone owns ninety-one cables, extending over 38,000 miles.

I presume you have all seen specimens of submarine cables, and many of you are more or less acquainted with the general method of their construction. It would be outside the object of this paper to describe the various forms. There are several extensive manufactories, each having its own style of construction. The chief objects for which manufacturers have striven have been great conductivity, high insulation, tensile strength, and small bulk. To this end generally the conductor is made of several small copper wires twisted together as one. A single conductor of the same amount of metal, would be too risky, for if it should break, continuity might be lost beyond repair for a long time. Injury to one of the small wires forming the composite conductors would not seriously interfere. The copper

forming the conductor is always of the purest. Then comes the insulation. Unless a cable conductor is well insulated, or protected from the water, the electric current, instead of making itself manifest at the distant end, will leak out into the water and complete a circuit through the earth to the point from whence it came. For it must be remembered, that the conducting wire, although made of the best conducting metal known, offers some opposition to the absolutely free passage of the current. This opposition, termed resistance, corresponds to friction. Now a cable from Ireland to Halifax has a pretty high resistance, amounting in some instances to twelve or fifteen thousand ohms or units of friction, while the entire earth only offers a resistance of a fraction of an ohm, or equal to the resistance of about fifty feet of the ordinary telegraph wire that you see on the poles. Therefore, as electricity is a great economizer of distance and time, never going an inch out of its way, it will go through a fault in the cable in preference to coming over to America. A hole in the protecting shield as big as the point of a pin will let the current out, and if it once gets started, even in a very small way, it will soon make an outlet for itself that will practically put a stop to all telegraphy. This will give you some idea of the necessity for perfection in the manufacture of cables. Of course, the full coating of insulation is not put on all at once. Three or four different coats are applied. Gutta-percha and compounds of a kindred nature are used. Tarred hempen twines are wrapped around the insulation. Then galvanized iron wires are twisted over the hemp, and sometimes they, in turn, are wrapped with fibrous material to protect them from the corrosive action of the water.

All cables are tested before leaving the factory. When put on shipboard, the ship's electrician is in constant communication with the shore through all the cable on the ship. The slightest fault is detected just as soon as it goes into the water. Paying out is immediately stopped, and the cable repaired. You could not see a pinhole in the insulation, but it can be located by the fine testing instruments, sometimes within a quarter of a mile in the entire stretch of 2,000 miles.

The best conductor is the worst insulator. The best insulator the worst conductor. The difference between the conductivity of pure copper and pure gutta-percha, cannot be expressed understandingly in figures. Somebody has calculated that if the difference was reckoned on the basis of the velocity of light, it would take the sunlight a century to reach the earth. Owing to great insulating properties of gutta-percha, but a fraction of current is lost between Europe and America.

People unacquainted with these matters would naturally think, with DeSauty, that so long a cable would require very powerful currents to operate them, but it is not so. There is quite as much battery used in working a wire between Philadelphia and New York as is used on the cable. The reason is mainly on account of the almost perfect insulation of the latter, little or nothing being lost, while in the case of the Philadelphia and New York overhead wire a large percentage of the current goes to earth at the poles. Besides, much coarser instruments are used on the land lines. It would injure the Atlantic cable to apply as much current power to it as it takes to work a land line from New York to Washington on a rainy day. All the current that goes into a well insulated cable at one end, must come out at the other. It would be much better if the insulation of the cable was less perfect. It could be operated much faster. My own opinion is that the great need in cable telegraphy is bad insulation, or a *good bad* insulating material. Something that will not go from bad to worse under the action of the current. Just at this time there is considerable discussion going on as to the necessity for armor wires for deep-sea cables, and also regarding their effect on the working of the cable. It is claimed by many that there is absolute rest at the bottom of the Atlantic, and that tarred hemp covering would be more durable than the armor wires. Many electrical authorities have held that the iron armor wires impede transmission, on account of their influence on the conductor, or magnetic induction.

The greatest living authority in such matters, Sir William Thomson, lays down the law, that while the retarding effects

of magnetic induction may be recognized in cables of about 100 miles in length, it is completely overshadowed in long cables by the greater retardation arising from static capacity. He even goes so far as to accept and indorse Mr. Oliver Heavesides' mathematical proof that magnetic induction increases the speed at which long cables may be operated. While it would be great presumption for me to differ with such eminent authority, I cannot help thinking that there is much of what Professor Tyndale would call "scientific speculation" in these views. I am strongly of the opinion that the unarmored cable would be much faster than the one bound with armor wires. Aside from electrical considerations, it is believed that armor wires are necessary to protect the cable from chafing on the rocks, and from the teeth of the parasite, which fares sumptuously on hemp, tar, gutta-percha, and other apparently indigestible substances. Everything is said to have its parasite, and it is proven that cables at the bottom of the ocean have not been overlooked. Cables have been taken up from a depth of a mile and a-half, with the hemp covering badly eaten away, and at a depth of over half a mile strong currents of the ocean have rasped the armor wires on the rocky bottom. To overcome this latter difficulty the shore ends of cables are always made much heavier and stronger than the deep water cables. Experience has not yet determined the full lasting qualities of electric cables. Specimens have been taken up which show no signs of deterioration after having been in the water for more than thirty-five years. Water, and especially salt water, seems to be a preserver of insulating compounds.

The method of operating cables has been so fully and learnedly explained in many books on electricity, that it may seem a waste of time to go over the ground in a less instructive way, but I do not intend to attempt more than a description, in simple language, of the elementary principles of operation, hoping thereby to be able to make clear to your minds the nature of my own endeavor in the direction of improvement, and in what respect it differs from the present plan. Almost everybody in these days has some knowledge

of how land lines are operated. They have become accustomed to seeing the operator manipulating his key, and although the click of the sounder has no meaning to their ear, still all know that the working of the key at one end of the line causes the sounder to work at the other end. Although not a country in Europe, except England, uses the sounder, the clicks, recorded in dots and dashes on the strip, have the same meaning. It is the only real Volapük language. The marks on the paper might be likened to the music score, while the sounder is the tune itself. We are admonished that we should believe nothing that we hear and but half that we see, but experience has proven that in

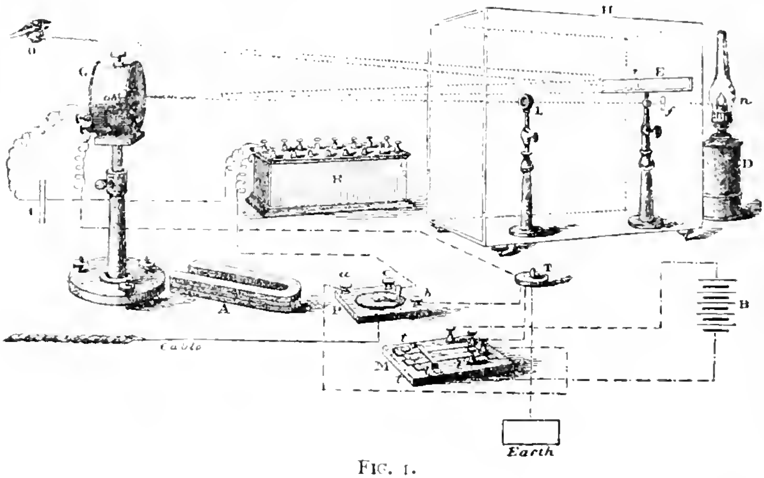


FIG. 1.

telegraphy the ear is more correct than the eye. Furthermore, telegraphy can be carried on much more rapidly by sound than by reading from the paper strip. We should be proud of the expertness of our American telegraph operators, for I doubt if there be on the entire continent of Europe an operator that could copy thirty words per minute by sound for five consecutive minutes. Our operators have to do this, or very near it, all day long.

It is not the fault of the foreign telegraphists that they are not sound-readers. They are, in the main, well educated, bright and intelligent, but the administrations have no confidence in this way of working, and refuse to trust it.

It was forbidden in this country up to about twenty-five years ago, but Young America couldn't plod where he could just as well progress, so the telegraph managers soon found that they were simply wasting paper. The operators read by sound.

On long cables, such as those across the Atlantic, the Morse relay and sounder are too coarse for the exceedingly delicate impulses that come through the cable. It might be possible to work a very sensitive Morse relay, but at an impractically slow speed of perhaps two or three words per minute. The cable would be clogged up by the strong currents required. The weaker the current the faster the speed; hence, everything depends on the sensitiveness and delicacy of the receiving instrument. The most sensitive of these is the Thomson reflecting galvanometer. (*Fig. 1.*) It consists of a small piece of steel, no thicker than a watch-spring and about three-eighths of an inch in length, suspended by the finest silk fibre in the centre of a coil of fine insulated copper wire. To this small steel compass is fastened a looking-glass, about as large as the blunt end of your lead pencil. Opposite this needle and its reflector, and perhaps three or four feet away, is a lighted lamp and a screen. In the centre of the screen is a neutral or zero point, where the beam of light reflected by the small looking-glass rests when there are no signals coming. A permanent magnet is placed in such magnetic relation to the small piece of steel as to cause the beam of light to return to the neutral point quickly after having been carried to the right or left by an impulse of current coming over the cable. Instead of using a single key and making dots and dashes with a current of one polarity, merely tapping the key for a dot, and holding it down for a longer time for a dash, as in ordinary Morse telegraphy, the present cable system requires *two* keys, one connected to a positive, the other to a negative battery. Now, assuming that a tap on the positive key will swing the beam of light to the right in Canada, that signal would be recognized as a dot. Then, if the other key connected to the negative battery be tapped, the beam of light will swing to the left of the zero line and will denote a dash. You will

observe that no dashes or long contact with the battery are admissible in this system, and the aim of the operator must be to make the taps on each key of the same duration, so that the reading light will return to its neutral position quickly and uniformly after each signal. This is the fastest system of ocean telegraphy in use.

The receiving apparatus is placed in a darkened room. The receiving operator calls off the letters one by one to a copyist who writes them down. It is tiresome work for the receiver, whose eyes must never leave the moving ray silently speaking to him from the other shore. To verify a letter of doubtful sound, a familiar word beginning with the letter is quickly pronounced. For example, after calling out

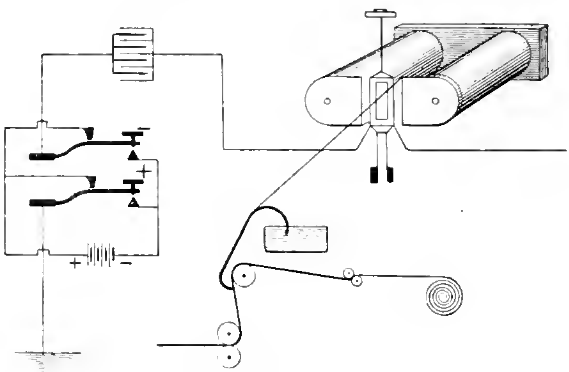


FIG. 2.

the letter D, the receiver might say "dog," so that the copyist could not mistake D for B, C, G or E. The average speed of transmission by this system is about fifteen words per minute for regular messages. A later and preferred system of cable signalling now in very general use is the Thomson Recorder System. The signals are recorded in ink on a paper strip. Although not quite as fast as the mirror system, and a little less sensitive, the recorder is recognized as a marvel of ingenuity and perfection, considering the work it performs under such difficult conditions. This rough diagram on the screen (*Fig. 2*) will show the arrangement of the transmitting keys and connections. Everything is the same as already described in connection with the mirror system,

but I wish to make it perfectly clear to you by the diagram, as it is between this system of transmission and my own system, which I am coming to soon, that I wish to draw a few comparisons. This diagram also gives an outline of the Thomson Recorder. In a few minutes I will show you on the screen a recorder complete. Referring now to the diagram before us, you will have no difficulty in following the circuit connections. We must assume that the recorder is at the distant end of the cable, and the keys, batteries

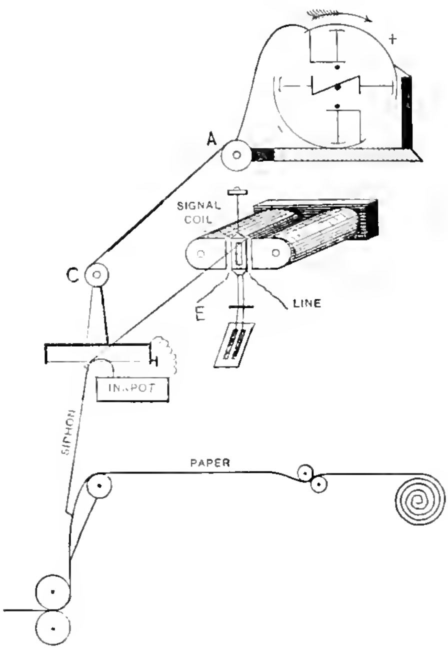


FIG. 3.

and condensers are at the transmitting end. In their present position, both transmitting keys are disconnected from the battery, and the cable is connected to earth. As but one key is pressed down at a time, the cable is connected to earth between each impulse. Now with the complete drawing of the recorder before us (*Fig. 3*), we can understand how the signals are received on the paper strip.

Instead of a small piece of steel suspended in the centre of a coil of wire, as in the case of the mirror instrument,

we have here a small coil of wire suspended between the poles of a powerful permanent magnet. The wire in this small coil is so fine that several pieces of it might be put in the eye of a cambric needle at the same time. It is suspended by a very slender silk thread. To the bottom of the coil two weights are attached, which bring the coil into proper relation with the lines of force of the permanent magnet, so that when an impulse is received from the distant end it brings about the greatest amount of swerve of the coil in a rotary direction. When the current swings the coil to the left, the right-hand weight pulls it back, and *vice-versa*. The siphon with one end in the ink-pot and the other resting on the paper strip, is attached to an adjustable support, and its lateral movement is controlled by a silk thread attached to the coil. Now, if the paper be pulled by the feed rollers, a straight delicate line in ink would be made in the centre of the strip. But with the siphon touching the paper, the friction of even this very delicate contrivance would be too great to be overcome by the swing of the coil under the influence of the faint impulses coming over the cable. To remedy this, Sir William Thomson devised a plan of surpassing beauty and ingenuity. This mysterious looking little arrangement, which you see here at the top of the figure, is a generator of static electricity.

It is frictional electricity, the same as you get from belts in your works, or from sliding your slippered feet across the carpet, the oldest electricity of which we have any record, unless, perhaps, it be the lightning that Ajax challenged. The Greeks made it by rubbing amber. Well, this is what Sir Wm. Thomson uses to relieve this little siphon of friction in its oscillations. The static generator is run by a small electric motor, generally known as a "mouse mill." The electricity ground out by this little mill is conducted by a damp string or wire to the ink in the ink-pot, which is well insulated from the base. It then finds its way through the ink in the small glass siphon to the paper, where it is discharged. The siphon, which is as fine as a hair, is normally adjusted so as to just escape the paper. The static electricity attracts the siphon to the paper, but

as soon as the ink touches the paper the current is discharged, causing the siphon to rebound. Thus, the siphon may not really touch the paper, but the ink is deposited in dots so close together as to form a practically continous line. The discharge and consequent vibration of the siphon will number, perhaps, fifty per second. In this way the small coil of wire meets with little or no hindrance in its movement and a permanent record is made on the strip which, if obscure or doubtful, may be scrutinized with deliberation. Not so with the mirror receiver. If a letter or word is not translated while the beam of light is swinging it is lost and must be repeated. This beautiful electro-static device for overcoming friction has but one drawback. It is quite difficult to confine the static current to its proper channels in damp weather. Its high potential makes it difficult of insulation. Mr. Cutriss, mechanician and electrician of the Commercial Cable Company, has devised and put in operation a very ingenious plan for obviating this difficulty and it does it most successfully. Instead of a static generator such as described, he fastens to the end of the siphon where it touches the paper a piece of iron about the size of a pin's head. Underneath the paper is an electro-magnet, the circuit of which is interrupted by an adjustable automatic vibrator.

In this way the small speck of iron attached to the siphon is attracted each time the circuit of the magnet under the paper is closed, and a vibration imparted to the siphon corresponding with the rate of the automatic circuit breaker, or, to be more correct, the circuit breaker is adjusted to the natural rate of vibration of the siphon.

Now, having considered the method of operation, we may analyze briefly the theory involved.

I will submit a few general proportions upon which to predicate a few deductions later.

The reason why relays and sounders are not used for cable work is that they require comparatively strong currents to affect them. Strong currents cannot be used, because they are injurious to the cable and prevent rapid signalling. The question arises then is it possible to make

a relay that will work with the present current pressure and make and break the local circuit of a sounder, so that signals may be received by sound at as high a rate of speed as at present obtainable by the mirror or recorder instrument?

It is a most hazardous thing in these days to say that anything cannot be done. I have no hesitation in saying that at no very distant day the Atlantic cables will be operated by relays and sounders, but not with the present system of transmission of the impulses. And I am also strongly of the opinion that the present mirror and recorder systems may also be operated at a considerably higher speed by a change in the method of transmission. Or, in other words, I maintain that the system of transmission which will make relays and sounders of the future work practicably on long cables is now available for the improvement of the speed of the present receivers. I alluded some ways back in this paper, to obstacles in the way of operating cables with the same facility that land lines are worked. I now return to that part of our subject, and if you will continue your patient attention for a short time longer, I hope to be able to make the cause and effects touched upon clear to you all. You all know the Leyden jar. That it comprises a glass jar with a coating of foil inside and another outside, each completely separated and insulated from the other by the glass. You also are well aware of the fact that if one of the coatings of metal be charged with positive electricity, the other coating will be inductively charged with electricity of an opposite polarity. It is the same with a condenser made up of sheets of tin-foil and separated from each other by sheets of paraffine or any high insulation.

A submarine or subterranean cable is nothing more than a Leyden jar or condenser. The conductor is one plate, the insulation is the glass jar, and the armor wires and water the other plate. Consequently, when a current impulse is sent into the cable, an opposing current makes its appearance on the outside and in the insulation. This unwelcome outsider weakens the real impulse in its passage through the conductor, and, worse still, takes possession of the conductor

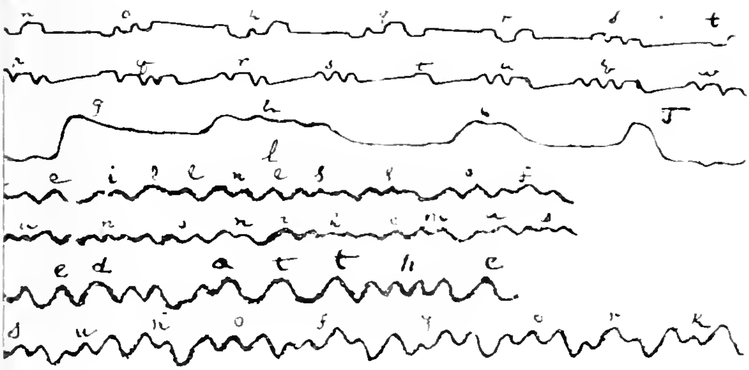
itself when the first current ceases, and opposes the entrance of the next current impulse.

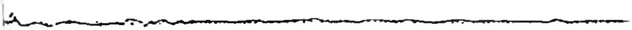
Thus it is, that, after each signal is sent into the cable, we have what is known as static discharge. It is only static, or in a state of rest, so long as the signal current is in possession of the cable, for when the cable conductor is put to earth, as is done after each impulse, as shown in the drawing, it runs out, most of it towards the end at which the signalling current went in, but some of it goes towards the distant end, prolonging the signal at that end much beyond its length at starting. Now, for the reasons already explained, currents, whether real or vagrant, travel slowly in the cable. It requires about one-tenth of a second for an impulse to cross the Atlantic.

If the cable conductor was on poles fifty feet above the surface of the water, the impulse would make a dozen round trips in the same time. Now then, after sending in one impulse, the operator cannot wait for the static discharge to run out completely. This would render transmission unprofitably slow. Another impulse must follow, but, owing to the blocking up of the way by the static current, it arrives delayed and depleted at the other end. In cable telegraphy, as at present conducted, I have shown that two keys are used—one for sending positive currents, the other negative, and representing dots and dashes respectively. Now then, if the letter A is to be sent, the positive key is first tapped and the siphon is carried towards the top of the strip. Then the negative key is tapped and the siphon is carried towards the bottom of the strip. These two movements up and down will represent A, and there is no mistaking it. This letter was formed of alternations of the current—positive and negative. It will be different with letter B. It requires four signals—a dash and three dots. The negative key is pressed down once, and immediately afterwards the positive key is pressed down three times in succession. Thus one negative current and three positive currents were sent. The effect of the negative impulse was to carry the siphon below the horizontal line representing the dash. The first of the three positive currents brought it back to a

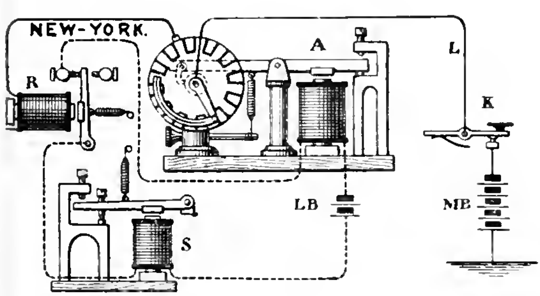
position slightly above the horizontal line. The second carried it a little further in the same direction, and the third still a little further. I have on the screen several specimens of cable records (*Fig. 4*). Although the variety is not great they are sufficient to show the effects of static capacity and retardation.

This 4–4 strip shows an alphabet in the Continental code, received over the Direct United States Cable Company's cable at Halifax, from, Ireland about three weeks ago. It is not a first-rate specimen, owing to the fact that the cable is generally worked with the mirror system, and the recorder was set up temporarily by the obliging management just to get me this record. It is a fair sample of every-day cable-work, however. This and the other strips on the diagrams which you have are one-third below the actual size, having been photographed down. You will see that the three dots of the letter B resemble three steps of a stair, but without the sharp outline, and you will observe that the last dot is less distinct than the second, and that the second is not as plain as the first. The dots in letter H answer the description even better than B. The explanation of this is that the first dot represents the scope of the swing of the suspended coil of wire under the influence of a reversal of the current from negative to positive. The second dot simply shows a slight fall in the potential of the cable, owing to the breaking of the current at the sending end, and the third shows a still smaller undulation. The cause of this is that, after the first dot was made and the battery withdrawn at the sending end, the static current continued to run out at the receiving end, still holding the siphon above the horizontal line, to which point it would otherwise have returned quickly, and in its exit at the transmitting end weakens the next dot coming in. The third dot shows that the cable was still more clogged up than when the second dot came through, and so on. If dots were sent continuously, there would be nothing but a straight line, provided the dots followed each other in reasonably rapid succession. It must not be inferred that additional dots would keep on carrying the siphon higher and higher, for






i s c o n t e n t


NEW-YORK.
A
R
L
K
S
LB
MB

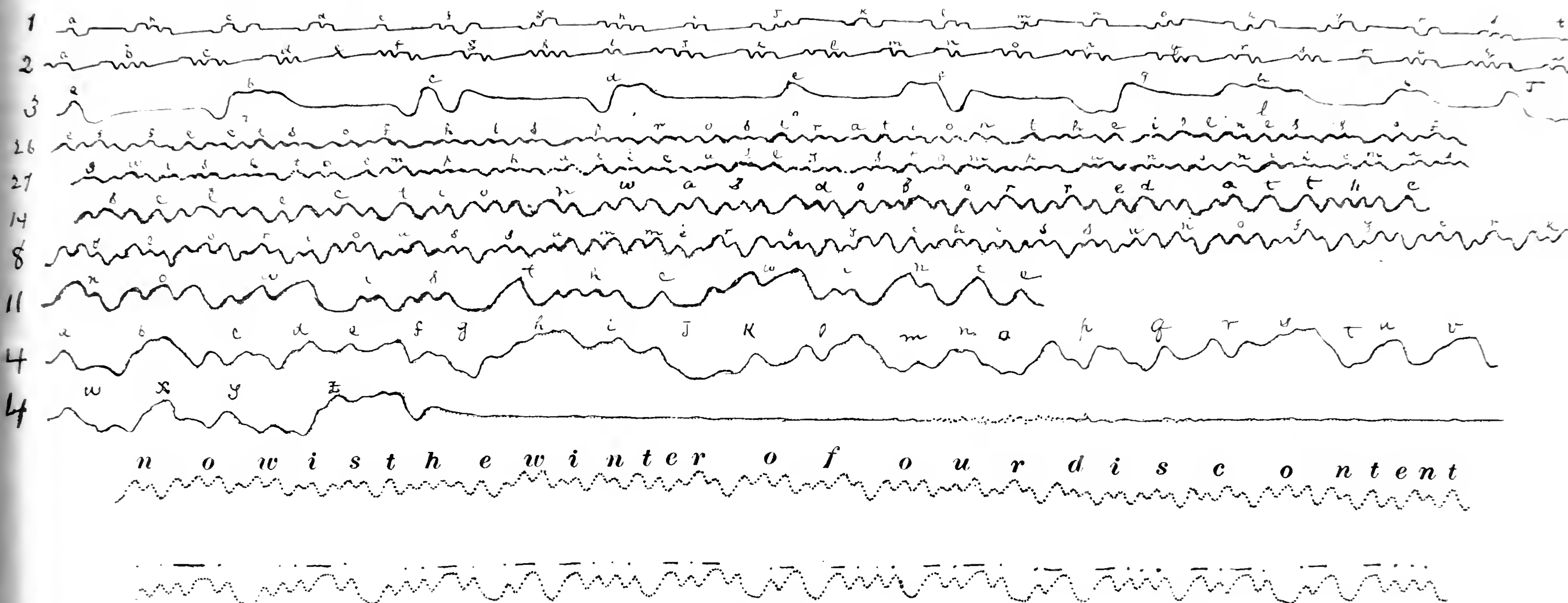


FIG. 4.—Cable Records.

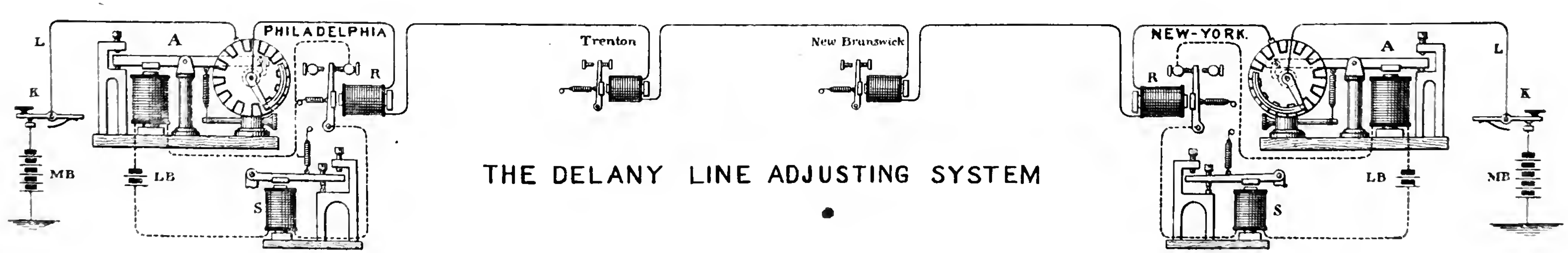


FIG. 6.

such would not be the case. The maximum influence of the current for turning the coil around is reached in three or four impulses, and if the current was permanently connected the siphon would make a straight line above or below the centre of the strip, according to the polarity of the current coming over the cable.

You will readily appreciate the degree of proficiency and experience necessary on the part of the cable operator to translate correctly these wavy lines and almost imperceptible undulations, especially when we remember that nearly all cable messages are in cipher, without meaning or context to aid the operator. The high charges have been productive of codes so constructed that a single word may, when translated, be as long as the Lord's Prayer. Ten letters are allowed to a word. If it goes one letter over it is charged for as two words. The addition or omission of a letter in a word may change the entire meaning of the cablegram. The cable operator must exercise wonderful judgment. When the dots or dashes are practically devoid of any characteristic but a straight line, he determines their number by the length of the line occupied by the doubtful letter. The strain on the mind is great, for fines are imposed for errors.

To facilitate business, and as a further safeguard against mistakes, in some offices two operators examine the strip as it comes from the instrument. The second operator verifies or corrects words indicated as doubtful by the first.

The most interesting and really wonderful telegraphing in the world is carried on by the Eastern Cable Company. Messages are sent from Bombay to Penzance, over a series of cables which, by what is known as the "Human Relay" system, is practically continuous. Bombay sends to Aden, 1,832 miles. An operator at Aden reads directly from the strip, and at the same time transmits to Suez, 1,403 miles. Suez in like manner sends to Alexandria, 154 miles. Alexandria operator sends to Malta, 925 miles. Malta repeats to Gibraltar, 1,125 miles. Gibraltar in turn sends to Lisbon, 383 miles, and finally the operator at Lisbon sends to Penzance, 891 miles. A total distance of 6,713 miles with-

out a word being written. This weird message of mankind enters ocean after ocean and sea after sea, bobbing up serenely at intervals, as though to get breath for a fresh dive. As nearly all cable circuits are worked upon the duplex plan in these times, this matchless transmission is not interrupted for corrections or missing words. The message is kept moving to the end, and if found wanting in any respect inquiry is sent back to Bombay on the other circuit. So that the routine goes on like an endless chain.

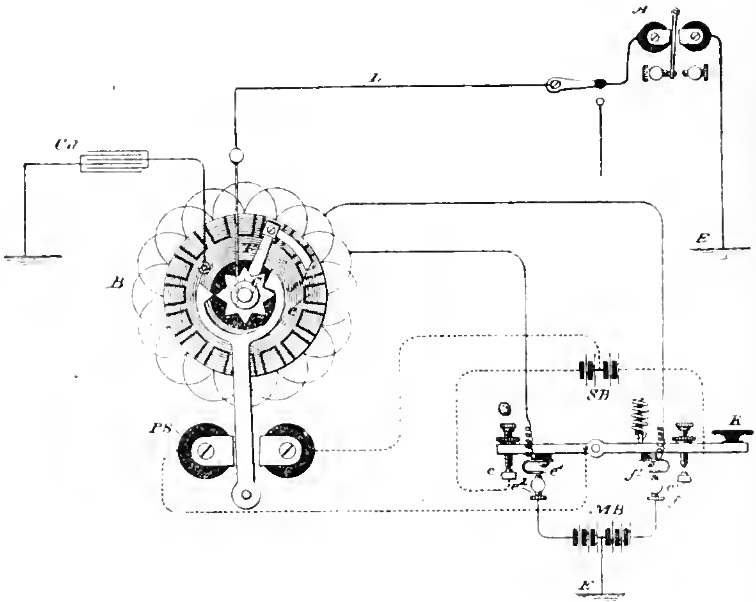


FIG. 5.

I do not think it necessary to take up any further time with the theory and practice of the present system, but will come at once to an explanation of my own system of transmission, which I will endeavor to make as short as possible. I must ask you to give me your attention while I have recourse to this excellent diagramatic view of the apparatus, (*Fig. 5*), and if you will bear in mind what has already been said upon the theoretical operation of cables, it will take you but a few minutes to recognize the difference between the systems explained to you, and the one I am about to

describe. The main features of this system are, that successive impulses of the same polarity are never sent into the cable. That each signal impulse is followed by another, which opposes and neutralizes the static charge in the cable, and clears the way for the next signal impulse. Also that all the signalling impulses are of practically the same duration, and that the clearing impulses are absolutely of the same duration. And, finally, that transmission is done by the use of an ordinary Morse key, so that any operator can send messages. The two-keyed system requires even more practice to become proficient than single key working.

I have explained to you how a series of impulses of like polarity may appear as a straight line on the strip at the receiving end, according to the frequency with which they follow each other. So also may regular reversals become almost a straight line if they are sent in sufficiently rapid succession, and they might be sent so quickly that no current at all would reach the receiving end, the discharge from one completely obliterating the next. They would strangle each other in the cable. I am convinced, however, that if each signalling current is immediately followed by a neutralizing current of electro-motive force, adjusted to the static discharge, the speed of signalling may not only be greatly increased, but the received marks will be unmistakable. In support of my claim, that by keeping the cable in a state of stable equilibrium by the neutralizing impulses, I would state that early last summer I transmitted 680 perfect impulses over a cable of nearly 1,000 miles in length, having a resistance of 13,000 ohms, and an electro-static capacity of 240 microfarads, and this with eight volts—just one-half of the electro-motive force used on this cable ordinarily. This is equal to more than thirty words per minute and the record was as even as if it had been engraved. In September last, I made two experiments over the Anglo-American cable between Duxbury, Mass., and St. Pierre, Island of Miquelon. This cable is 878 miles in length, has a resistance of 8,300 ohms and a capacity of 256 microfarads. The result of these experiments, hurried and unprepared as they were, I have endeavored to bring to your attention on

a small scale by having the records reproduced in *fac-simile*. You will find them on the sheet.

Owing to the faint lines made by the recorder, and to the fact of the ink being blue, it was necessary before photographing to go over the strip with pen and ink, which has, to a considerable degree, robbed them of their smooth outline, so that they do not appear to as good advantage. If you will look at the sheet, I will give the record of each specimen beginning at the top. Number 1 is a portion of the continental alphabet, not sent over the cable, but made locally at Duxbury by the present system of transmission, and by throwing the duplex a little out of balance. It may be considered an ideal specimen. The dots are above, the dashes below the horizontal line, represented by the long straight lines between each letter.

The dots you will remember are all made by one polarity of current, the dashes by the other. No signs of the clogging effect of static capacity are visible in this strip, because the signals were not sent through the cable. Number 2 is by my system of transmission, made under the same conditions. My transmitter puts both dots and dashes at the top, or above the horizontal line. Telegraphers must bear in mind that this is the Continental code, several letters of which differ in construction from our American Morse. I consider the foreign alphabet better than ours. There are no space letters, consequently less liability to error. Our code is faster, however. The Continental C, is an American J; our Q is their F. Their R is our F; an American X is a Continental L, and so on. It is somewhat puzzling for a sound-reading operator, knowing both alphabets, to read first one and then the other by sound without confusion. I have had some experience with this sort of thing myself. On one occasion I asked an English operator over the wire how my system was working, when he answered back "axx fight," I was content. Now telegraphists will recognize a dot and a dash for A. Dash and three dots for B, and dash dot, dash dot for C, dash and two dots for D, one dot for E, etc. Specimen number 3 was received over the Anglo-American Cable at Duxbury from St. Pierre. By the long waits between the

letters you will see that it was sent at a very slow speed, perhaps eight or nine words per minute. Here we have the effects of choking up of the cable by succeeding impulses of like polarity beautifully illustrated. Observe letter B—a dash and three dots. The lower loop is the dash, the undulations at the top the three dots. Compare these with the letter B in specimens 1 and 2, which were made on a local circuit. The dots in D, F, H and I show the same difference, also the dashes where they succeed each other as in G—two dashes and a dot. Now you will see that if the cable had not the capacity for storing electricity the record three would be like 1 and 2, plain and rapid.

You may say you do not see in specimen 3 the step-by-step feature referred to awhile ago as resulting from successive dots of like polarity. It is because the cable is not a very long one—less than 900 miles—and the speed at which this record was made was so slow as to allow the siphon to drop down between each dot.

I will call your attention to this effect again in specimen 4, sent across the Atlantic. This is the alphabet complete. B, D, H and I show what sort of a passage the poor struggling dot has to contend with coming under the Atlantic. If you will examine this closely, you will see the original line of dots in some places where the tracing pen went slightly to one side. The straight line at the end is the horizontal or neutral line made by the recorder when there was no current in the cable. The break-up in the middle, which looks like the splutter from a pen, was probably caused by a jolt of the table or a jarring of the floor. All the other specimens are some of my own transmission from Duxbury to St. Pierre. These specimens are odds and ends, picked up after the best specimens had been distributed. I have a number of specimens pasted in my book collection here, which are infinitely better than those shown you. Had it been possible to photograph them without inking them over, I would have done so. In fact, none of the specimens shown you represent the best adaptation of my system of transmission, but I will be glad to show those interested cable strips, that any telegraph operator can read, sent at twenty to thirty words per minute.

Specimen number 11 was at the rate of thirteen and one-half words per minute. You will notice a great difference between the dots in the specimen and those in specimen 3, sent by the present system from St. Pierre to Duxbury, and at a speed of not over ten words per minute. You can judge of the relative difference in speeds by the condensation or elongation of the characters on the strip. The paper runs through the instrument at an even speed always.

Specimen number 8 was at the rate of eighteen and four-fifths words per minute. The first letter is G, the next L. The photograph process has made the printed letters indistinct.

Specimen 26 was at the rate of twenty-six words per minute. This specimen, as well as 27, are according to the American code. The pen-tracing has injured them badly. They have been reduced one-third by the photograph.

Owing to a misunderstanding, I had but one-half the battery that I was entitled to when these specimens were made. All these things combined is the cause of the small undulations, although the specimens I have in my book are very plain, even number 27, which was transmitted by a Western Union operator who could not send a word by the two-key or cable system. The speed of this 27 specimen was a fraction over thirty-four words per minute. You will see that, even in this specimen, the dots are quite as distinct at thirty-four words per minute as they are in specimen 3, at ten words per minute, and 3 had double the electro-motive force behind it that was given to 27.

The last two specimens, those without numbers, are perfect *fac-similes* of my best work between Duxbury and St. Pierre. Every dot is carefully reproduced. The first of the two, "Now is the winter," etc., was transmitted at the rate of twenty-two and one-fifth words per minute, five letters to a word. The other, at the rate of twenty words per minute. The transmission in both cases was made *direct* to the cable, not through condenser, and with 100 microfarads condenser connected to the intermediate segments for the purpose of neutralizing the static discharge in the cable.

I was compelled to take the condenser out of the cable for this purpose, it being the only one available. These, as these two reeords plainly show, were by far the best conditions for working, and this is the arrangement with which I hope to work the Atlantic cables by sound, at no very distant day.

A study of these specimens will, I think, show conclusively the difference between merely breaking the circuit, depending on the drop in the potential of the cable for the signal, and reversing the current each time that a signal is sent, thus drawing the siphon to the other side of the horizontal line.

I wish to eall your particular attention to one result obtained between Duxbury and St. Pierre with my system of transmission, of which I have no wavy tracing to show you. It was not that kind of a result. I sent twenty words per minute for five consecutive minutes, and every dot and dash were received perfectly in St. Pierre *by sound*. At twenty-four words per minute, St. Pierre reported the work a trifle shaky, but the gentleman receiving reported that he had had but little experience in adjusting the Brown and Allen relay, which was connected on for the occasion. I am confident that this circuit can be worked perfectly by sound at thirty words per minute. Repeated efforts during the past twelve years have failed to get more than three or four words per minute over this cable by sound.

If you will now take up the diagram of the transmitter and connections which you have, you will find no difficulty in following me while I explain the method and theory of the instrument. (See *Fig.* 5.)

A represents a receiver at the distant station. An ordinary polarized relay is shown, but it might be a mirror instrument or a Thomson recorder, both of which have been described, or any other receiver. One side of the relay is connected to earth. To the other side is connected the line *L*, or cable. This line is connected to the revolving trailer *T* of the polarized transmitter *PS*. The trailer is carried by the spindle of star-wheel *C*, revolved by the pallet end of the armature of *PS*. *Cd* is a condenser connected to the plate

which projects between the segments in the circle. There are two sets of segments e and f in the circle besides the plate segments. Set f is connected to insulated contact f' under the front of the key. Segments e are connected to the insulated contact e' at the other end of the key. Contacts f^2 and e^2 are connected respectively to the positive and negative poles of a main transmitting battery *MB*, which is grounded in the middle. The key is connected to the polarized transmitter *PS*, thence to the middle of local battery *SB*, the ends of which are connected to the contacts c and c' under the back and front ends of the key. As everything now stands, the cable is entirely disconnected. The operation is as follows: If the key *K* be pressed down the positive pole of battery *MB* is connected to the cable through contacts f^2 and f' and segment f, upon which the trailer is resting. When the key reaches contact c', which is its limiting stop, the local circuit of magnet *PS* is closed and the armature thrown to the right, which moves the trailer off of segment f and breaks the connection between the cable and the main battery. Now, then, if you will look closely, you will see that the trailing finger is slanting, so that it bridges segment f and the intermediate or plate segment connected to the condenser while it is passing from segment f to the next segment, above which is one of the e set, and in doing so connects the positive pole of the main battery *MB* to the condenser, thereby charging it. When the trailer leaves segment f and touches only the condenser segment, the charge which the condenser received, while the trailer bridged the two segments is sent into the cable and meets and neutralizes the static discharge created by the impulse which went into the cable when the key was closed and the trailer was on segment f. The trailer does not stop on the condenser segment, but passes over in one movement of the armature of *PS* to the next segment group, which is connected to the contact e' at the back of the key.

Now, if the key be raised the negative pole of the main battery *MB* is connected to the cable through contacts e^2 e', segment e and the trailer. Immediately that the key reaches its limit, contact c, the local battery *SB* is reversed through

PS, and the armature moved to the left again, which terminates the contact of the negative pole of the battery with the cable, charges the condenser and discharges it into the cable as before, thus neutralizing the static discharge coming out of the cable from the negative impulse sent in. In this way, signalling impulses of alternative polarity are sent into the cable and discharge impulses from the condenser neutralizes the static charge in the cable. The force of the condenser discharge may be adjusted to the capacity of the cable by the use of resistance in the condenser circuit. You will observe that the duration of the contact of the cable with the main battery is determined by the time f', f^2 or e' e^2 come together in advance of the local contacts c',c^2, which reverse the circuit of the transmitter *PS*, plus the time required for the trailer to pass off of the segment. This time may be lengthened or shortened, within limits, by adjusting the key contacts. I have, however, a plan for lengthening the duration of contacts, which affords a much wider range, and by which the impulses may be adapted to any length of cable.

THE DELANY LINE ADJUSTER.

I have kept you so long already, I hesitate to claim your attention further. But I have something here which comes nearer home to all of us than cable telegraphy, and which is of the first importance in land telegraphy, more especially on railways. Indeed, I think it promises to become as useful to the telegraph line as the air-brake is to the train. It requires but little explanation, as I have the system set up, so that it can speak for itself. The apparatus is known as the LINE ADJUSTER. This is a comprehensive title to telegraphers. Relay adjuster would be more correct, but as it keeps all the instruments on the line in adjustment, I have given it the broader name of "Line Adjuster."

I presume that nearly everybody knows that land telegraphs work much better in dry weather than in wet. Every one here must be electrician enough to appreciate this one fact, after all they have heard this evening about the

current running down the poles. A little loss, as I have told you, is a good thing, but a rainy day is too much of a good thing for the telegraphs, as it robs the wires of too much current. In such weather the instruments need careful adjustment. At way stations the operators are not usually as proficient in this regard as they might be. Their instruments being out of adjustment, they do not hear other stations calling them, and if they have a message to send, they "break in" on the work going on over the line, calling away and not hearing the answer. How often have we been forced to listen for an hour at a time to uninteresting conversations going on between two oblivious youngsters, while life and death messages hung on the hooks, waiting for them to finish or adjust their instruments? I will not ask how often we have been there ourselves, for we have the floor, but all must admit that interference and failure from causes of this kind are the loudest crying evils of telegraphy. This adjusting system will do away with the difficulty thoroughly, for, so long as the terminal stations are adjusted, all the intermediate instruments *must* respond. Here we have an excellent diagram of a line between Philadelphia and New York, with Trenton and New Brunswick shown as way stations. There are, I suppose, forty telegraph stations between Philadelphia and New York. So many instruments in a line make it work badly. Now, if a rain-storm comes up, the current from the main batteries at Philadelphia and New York runs down the poles to ground. If the rain made a perfect earth connection, instead of a partial one, of course Philadelphia could work with no one beyond the point at which the line was wholly grounded. If we should run a wire from line to earth between Trenton and New Brunswick, Philadelphia and Trenton could communicate with each other, but could not reach New Brunswick or New York. In the same way, in bad weather, a station near Philadelphia—Frankford, for instance—will have no difficulty in working with Philadelphia, but, owing to the partial ground connection beyond him, he cannot get Trenton, New Brunswick or any other station so well. It might be that, although adjusted for Philadelphia, his instrument would

remain silent when New York was working. If he adjusted his instrument properly, so as to get New York, he could also work with Philadelphia on the same adjustment, but operators do not always exercise this discretion.

Now it is just here where this adjuster comes in and insures against the carelessness or inefficiency of the operator. After going over the diagram on the paper, I will create an artificial rain-storm between Trenton and New Brunswick, and prove to you that this little instrument keeps things straight all along the line. Please look at the diagram, *Fig. 6.* The instrument *A* is the adjuster. It is the only addition to the usual outfit. The key *K*, at Philadelphia, is down, or closed. The main battery goes to the segment plate upon which the trailer is resting, through the trailer to the relay, and thence on through the instrument at Trenton and New Brunswick to the New York relay, to the segment of his adjuster, through the trailer to the key *K* and main battery to earth. Here we have a closed circuit. Now ordinarily when Philadelphia wishes to send to New Brunswick, or any other station, he begins by opening his key, thus disconnecting his battery from the line. This causes all the relays and sounders on the line to respond if they are adjusted, but if it be a bad day, and there be considerable connection to ground down the poles, New York's battery being still connected to the line, finds its way to the ground all the way to Philadelphia and makes a circuit for the instruments at New Brunswick and other stations along the road almost as strong as before the withdrawal of Philadelphia's battery, consequently New Brunswick's instrument remains silent and the operator does not hear Philadelphia call him, or Philadelphia may be sending to Trenton or New York, but New Brunswick thinking the lines free may call Philadelphia and abuse him for not answering calls promptly. This is what is happening every rainy day all over the country, but it cannot happen under the organization before you, for when Philadelphia opens his key he not only takes his own battery off, but if New York be adjusted, the battery at that end is disconnected also, only for an instant, but sufficient for the purpose, as the line is left

with absolutely no current for a moment, during which every relay on the line must respond. I will not attempt a detailed description of the operation. It is not necessary. You see that when I put in a partial earth connection between Trenton and New Brunswick, and with the adjuster at New York made inoperative by throwing the switch over to the left, New Brunswick's instrument does not respond to Philadelphia's call as it did before the rain-storm began. Trenton gets Philadelphia all right, because he is between Philadelphia and the storm. New York gets Philadelphia because his instrument is adjusted. If New Brunswick would pull up on his relay spring he would hear Philadelphia also, but he hears New York and imagines he is all right. Besides, he heard Philadelphia before the rain soaked the poles and covered the insulators with a sheet of water. Now I will throw the switch of New York adjuster over to the right. Let us see what effect it has on New Brunswick. You see his instrument works now all clear and will continue to do so no matter how hard it rains, so will all the instruments on the line. There will be no more interference and no more calling a station for hours at a time. If an operator breaks in or fails to answer promptly he can't say that his instrument was out of adjustment. The adjuster says no.

I have *talked* so long, I will say a word to you with my fingers on the electric light bulletin. The simplest telegraph in the world. Everybody can send and receive, and if the letters on the transparency be large enough, announcements may be read a mile away.

There is an electric lamp behind each letter, and all the operator has to do is to press the button of each lamp on this little keyboard. This will be a great scheme for advertising, giving election returns, etc.

I thank you sincerely for your patient attention.

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, June 18, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 18, 1889.

Mr. H. PEMBERTON, Jr., President, in the Chair.

Members present: Dr. S. C. Hooker, Dr Wm. H. Wahl, Prof. S. P. Sadtler, Dr. L. B. Hall, Mr. Reuben Haines, Mr. Wm. H. Bower, Mr Fred. E. Ives, Prof. E. F. Smith, Mr. W. L. Rowland, Dr. H. W. Jayne, Mr. Lee K. Frankel, Prof. N. Wiley Thomas, Dr. Wm. H. Greene, Prof. R. L. Chase, Mr. J. H. Eastwick, Mr. A. T. Eastwick, Mr. A. W. Allen, Dr. Geo. A. Koenig, Mr. W. W. McFarlane, Mr. W. D. Weikel, Dr. Wm. C. Day and two visitors.

The President read a letter from Mr. M. Carey Lea, transmitting specimens of the various allotropic modifications of silver obtained by him, and stating that absence from the city prevented his attendance upon the meeting.

The President presented a letter from Prof. F. W. Clarke to Dr. Greene giving information in regard to the proposed formation of a National Chemical Society. He also read a copy of a letter from Professor Remsen to Prof. A. B. Prescott, reporting unfavorably upon the suggestion to make the *American Chemical Journal* the organ of the proposed National Society.

After some discussion it was voted that Dr. L. B. Hall and Dr. Geo. A. Koenig be appointed delegates to represent the Section at the next meeting of the American Association for the Advancement of Science, upon the question of the formation of a National Chemical Society. Further consideration of the subject at present was, on motion, tabled.

Dr. Hooker read his monthly report on the Philadelphia Water Supply. The report contained facts of much importance and interest, from the sanitary standpoint, particularly with reference to the Kensington pumping station, which draws its supply from the Delaware River. The paper was referred for publication. It concluded with a resolution recommending the

condemnation of the Kensington station by the FRANKLIN INSTITUTE; the motion to adopt this resolution was carried by the Section.

Mr. Fred. E. Ives then exhibited on the screen, with the projecting microscope, specimens of various crystalline substances under the influence of polarized light.

The President then read an abstract of Mr. M. Carey Lea's paper on allotropic forms of silver and exhibited specimens of the various modifications. The subject was received with much interest by the Section.

Dr. Smith and Mr. Frankel presented a paper on "Electrolytic Separations," which was referred for publication.

Dr. Greene read a letter from E. Paternò in regard to lapachic acid and its derivatives. It was referred for publication.

Adjourned.

WM. C. DAY, *Secretary.*

ERRATUM (to minutes of April meeting): The following gentlemen were elected members of the Section at the April meeting; a statement of their election was inadvertently omitted in the minutes of that meeting: Dr. L. I. Morris, Dr. Persifor Frazer, Mr. Fred. E. Ives, Mr. Theodore D. Rand.

ON THE PREPARATION AND PROPERTIES OF METALLIC MANGANESE.

BY CHAS. BULLOCK.

[*Read at the Stated Meeting of the Chemical Section, May 21, 1889.*]

The properties of manganese, like those of iron, appear to differ according to the method used in the reduction of the metal. When obtained from the oxide by heating with carbon, most authorities agree in the statement that the metal oxidizes so readily in the air that it can be preserved only under "rock oil," or in well sealed vessels. In water it is said to "oxidize rapidly, with evolution of hydrogen, and crumbles into a dark gray powder."

Cast manganese containing eight per cent. of iron is said to be unalterable in the air.

In the year 1869, some manganese prepared by me after the process of Brunner (the reduction of the chloride mixed with fluorspar, by means of sodium) was found to have as little tendency to oxidation as iron.

Repeating recently this process, pure chloride of manganese was fused in a clay crucible and poured on a stone slab, when cold it was pulverized and mixed with an equal weight of powdered fluorspar. This mixture, divided into portions of one ounce, was introduced into a French clay crucible, previously heated to redness. Eighty grains of sodium, cut into small pieces and freed from naphtha, being added to each portion, the crucible was covered, and reaction allowed to take place before adding another charge. After six ounces of the mixture had been added, the contents of the crucible was covered with fused chloride of sodium in powder, the cover replaced and the heat carried to quiet fusion. After the flux became entirely fluid, the heat was continued for ten minutes. The crucible was then removed from the fire, and after cooling the metal was found as a button at the bottom.

Three crucibles, of the capacity of eight fluid ounces each, were used at a time in a furnace without artificial blast. Care is necessary not to urge the heat too high, otherwise the crucibles will not resist the action of the fluorspar flux. The French clay crucibles were used on account of their greater freedom from iron and silica; they also resist the flux better than the Hessian, black lead or iron crucibles.

The yield of manganese under favorable circumstances, was about twenty per cent. of the chloride used.

Reduction was also tried by using fused chloride of sodium without fluorspar, the yield of metal was much less and differing in some of its properties from that obtained with the use of fluorspar. Manganate of soda was formed when sodium chloride alone was used as a flux.

Manganese thus obtained is very brittle, with a steel white fracture, so hard that a file will scarcely touch it, the edges of the fractures scratch, and almost cut, glass.

The metal retains the brightness of a fractured surface after prolonged exposure to the air, and appears not more disposed to oxidation than iron. It is entirely passive to magnetic attraction.

The specific gravity of the metal obtained when fluorspar was used was 7·072, when re-melted under fused sodium chloride, the sp. gr. rose to 7·153.

On the PRESENT CONDITION of the PHILADELPHIA WATER SUPPLY. THIRD MONTHLY REPORT.

By Samuel C. Hooker, Ph.D.

[*Read at the Stated Meeting of the Chemical Section, June 18, 1889.*]

In my last report presented to the Section, a month ago, I recommended that the Kensington pumping station be dismantled. I did not, however, deal with the Kensington supply as fully as I now propose to do, as there appeared to be a reasonable hope that this station would only be resorted to in the immediate future in the event of an unexpected break-down occurring at one or other of the stations on the Schuylkill.

This hope, which was based upon statements emanating from the Department of Public Works, has, however, been shattered during the past month, and the importance of the subject is so great that I feel I cannot do better than devote this report entirely to its consideration.

I wish it, at the outset, to be distinctly understood that whatever is said in this report refers exclusively to the water drawn from the Delaware at the Kensington station, and does not have any bearing whatever upon the city supply as a whole. While I shall presently speak strongly against the water pumps at the Kensington Works, the experience of the past month has strengthened the fairly favorable conclusion to which I had previously come and which has been already expressed in my last two reports, regarding the actual quality, aside from muddiness, of the Schuylkill water, which, as is well known, forms the bulk of the city supply.

The Kensington district is at present supplied from the Delaware at Kensington, from the Delaware at Lardner's Point, and from the Schuylkill.

Two thirty-inch mains, the one conveying water from the Wentz Farm reservoir, the other from the Schuylkill, make

connection with the Lehigh basin, which supplies the district. The Kensington pump also discharges into the Lehigh basin.

In spite of all efforts which can be made by the Water Department, under existing circumstances, the water carried through the two mains just referred to, from the Schuylkill and from the Wentz Farm basin, is not sufficient for the requirements of the neighborhood, and consequently the level in the Lehigh basin gradually sinks, pressure diminishes, and finally complaint of short supply reaches the Department. Nothing remains but to start up the pump at Kensington, and to continue drawing water from the Delaware until the reservoir is again filled. I thoroughly believe that the necessity of abandoning the Kensington station is fully realized by the Chief Engineer of the Water Department, but he is powerless to cause this to be done until some adequate provision is made for meeting the requirements of the district.

The bulk of the water drawn at the Kensington Works is supplied to the sixteenth, seventeenth, eighteenth, nineteenth and thirty-first wards. This district, as is well known, is the unhealthiest portion of the city. That the water is in a great measure responsible, there can be no doubt; to say that it is entirely responsible, might possibly be stating the case too strongly.

It is proposed to carry a forty-eight-inch main from the Schuylkill, in place of the thirty-inch main now existing, but this cannot be done without money, and until the sum necessary for this purpose is appropriated, pumping from the Delaware at Kensington must continue to a greater or less extent.

For years past the money which has been placed at the disposal of the Department has been very far short of that required for its imperative needs, and this state of affairs promises to continue unless some action is taken by the general public in asserting its rights and insisting that they shall be respected.

Whatever difference of opinion may exist regarding the wholesomeness of the Schuylkill, there is absolutely none

possible regarding that of the Delaware at Kensington, and it cannot be too strongly insisted that this foul, sewage-polluted water shall be no longer used for city supply, even though its poisonous and filthy character is partially or entirely disguised by admixture with large volumes of water from the Schuylkill and from Lardner's Point.

It is simply impossible for the sewage discharged into the Delaware, in the neighborhood of the Kensington Works, to be in any degree purified before it is taken up by the pump and distributed to the helpless population of the sixteenth, seventeenth, eighteenth, nineteenth and thirty-first wards. What wonder, then, that the Kensington district is a very hot-bed of disease in this city?

For nearly thirty years, this water from the Delaware at Kensington has been repeatedly condemned as *unfit for use* by Health Boards, by the engineers of the Water Department, by the experts who have examined into the matter, by every one, in fact, whose scientific knowledge has been sufficient to enable a clear estimate to be formed of the danger of supplying this sewage-saturated water to the community. Common sense rebels against it, the records of the Health Office silently protest against it, and yet for thirty years this pumping from the Delaware at Kensington, from a station which ought never to have been established, has been continued.

For a great number of years it has been the purpose of the various administrations of the city to abandon the Kensington Works, and it may be well to inquire how it happens that in spite of such good intentions these works still exist. The recommendations suggested by the various engineers of the Water Department, if carried out promptly at the time they were made, unquestionably would have enabled the Kensington station to fall into disuse, but unfortunately they were allowed to remain so long unacted upon, that when finally put into effect, instead of being able to supplant the Delaware supply for which they were originally devised, they were only able to meet the additional requirements of the district, due to its growth in the meantime.

It has been argued that the quantity of water pumped at Kensington is insignificantly small compared with the total supply of the city. So much the better; but instead of being a good reason for the water to be tolerated, it makes substitution of better water all the easier, and therefore all the more to be insisted upon.

Let me now refer to a few extracts from the reports of the Board of Health. The first is taken from the report for the year 1862, p. 13:

"One of the most serious and aggravated nuisances which has attracted the attention of the Board was the water supplied by the Kensington Works. After a careful investigation, based upon personal observation, as well as the experience of several physicians practising, and the analysis of a practical chemist, the Board, in May last, declared the water therefrom furnished to be a nuisance, prejudicial to public health, and so notified Councils. * * * *We are of the opinion that the only permanent remedy will be the total abandonment of the Kensington Works.*"

In the report of the Board of Health for 1866, p. 10, occurs the following:

"*All things considered* [the water] *is a sanitary evil of so dangerous a nature to the health of the inhabitants of those wards through which it is distributed, as to demand at the hands of Councils its immediate disuse.*" (The Chief Engineer, after an allusion to the alterations since made, says: "*I regard it as certain that the supplying of pure, or in any considerable degree suitable, water, for domestic purposes, from the river Delaware at the location of the Kensington Water Works, is impossible.*")

"Notwithstanding the improvement in the induction passage from the river to the pumps there has been no improvement in the water itself, nor can there ever be whilst the present supply of Kensington water is derived from the river Delaware at the present location. It will be evident to every disinterested visitor to the Kensington Water Works that a supply of pure water is impossible. The sewers opening into the river Delaware discharge their contents at a rate of an average of about 13,000,000 gallons daily, which necessarily includes every description of

possible regarding that of the Delaware at Kensington, and it cannot be too strongly insisted that this foul, sewage-polluted water shall be no longer used for city supply, even though its poisonous and filthy character is partially or entirely disguised by admixture with large volumes of water from the Schuylkill and from Lardner's Point.

It is simply impossible for the sewage discharged into the Delaware, in the neighborhood of the Kensington Works, to be in any degree purified before it is taken up by the pump and distributed to the helpless population of the sixteenth, seventeenth, eighteenth, nineteenth and thirty-first wards. What wonder, then, that the Kensington district is a very hot-bed of disease in this city?

For nearly thirty years, this water from the Delaware at Kensington has been repeatedly condemned as *unfit for use* by Health Boards, by the engineers of the Water Department, by the experts who have examined into the matter, by every one, in fact, whose scientific knowledge has been sufficient to enable a clear estimate to be formed of the danger of supplying this sewage-saturated water to the community. Common sense rebels against it, the records of the Health Office silently protest against it, and yet for thirty years this pumping from the Delaware at Kensington, from a station which ought never to have been established, has been continued.

For a great number of years it has been the purpose of the various administrations of the city to abandon the Kensington Works, and it may be well to inquire how it happens that in spite of such good intentions these works still exist. The recommendations suggested by the various engineers of the Water Department, if carried out promptly at the time they were made, unquestionably would have enabled the Kensington station to fall into disuse, but unfortunately they were allowed to remain so long unacted upon, that when finally put into effect, instead of being able to supplant the Delaware supply for which they were originally devised, they were only able to meet the additional requirements of the district, due to its growth in the meantime.

It has been argued that the quantity of water pumped at Kensington is insignificantly small compared with the total supply of the city. So much the better; but instead of being a good reason for the water to be tolerated, it makes substitution of better water all the easier, and therefore all the more to be insisted upon.

Let me now refer to a few extracts from the reports of the Board of Health. The first is taken from the report for the year 1862, p. 13:

"One of the most serious and aggravated nuisances which has attracted the attention of the Board was the water supplied by the Kensington Works. After a careful investigation, based upon personal observation, as well as the experience of several physicians practising, and the analysis of a practical chemist, the Board, in May last, declared the water therefrom furnished to be a nuisance, prejudicial to public health, and so notified Councils. * * * *We are of the opinion that the only permanent remedy will be the total abandonment of the Kensington Works.*"

In the report of the Board of Health for 1866, p. 10, occurs the following:

"*All things considered* [the water] *is a sanitary evil of so dangerous a nature to the health of the inhabitants of those wards through which it is distributed, as to demand at the hands of Councils its immediate disuse.*" (The Chief Engineer, after an allusion to the alterations since made, says: "*I regard it as certain that the supplying of pure, or in any considerable degree suitable, water, for domestic purposes, from the river Delaware at the location of the Kensington Water Works, is impossible.*")

"Notwithstanding the improvement in the induction passage from the river to the pumps there has been no improvement in the water itself, nor can there ever be whilst the present supply of Kensington water is derived from the river Delaware at the present location. It will be evident to every disinterested visitor to the Kensington Water Works that a supply of pure water is impossible. The sewers opening into the river Delaware discharge their contents at a rate of an average of about 13,000,000 gallons daily, which necessarily includes every description of

impure and refuse matter from the city, and of late years this impurity is much increased by the construction and connection of numerous water-closets with the sewers, from both public and private dwellings. A further deterioration necessarily occurs from the emptying of Gunner's Run and Cohocksink Creek into the Delaware, together with the large amount of human and other offal deposited in the river at Richmond. * * *

"The action of the tides, the movements of steamboats and the general traffic on the river, keep in suspense and carry a large portion of the impurities from the sewers from Gunner's Run and the Cohocksink Creek far beyond the present mouth of the induction tube at the end of the wharf. * * * When we know from our bills of weekly mortality that out of 277 deaths from *cholera Asiatica*, 132 (or 47 per cent.) have occurred in those wards supplied with the Kensington Delaware water, we think we shall be borne out in the opinion that the prevalence of the disease in those districts is not only occasioned by the use of the water as a prominent cause, but that it is so deteriorated in quality as to make it unfit for domestic purposes, dangerous to health and life, and therefore your committee would declare it to be a nuisance prejudicial to health, and would offer the following:

"*Resolved*, That the Kensington water supply as taken from the Delaware is a nuisance prejudicial to public health, and that Councils be urged by this Board to discontinue the supply at the earliest practicable moment, as the only remedy for the removal of the nuisance and the protection of the health of the district supplied therewith."

If this was the condition of affairs nearly twenty-five years ago, with how much more force do these arguments apply at the present time, when the amount of the sewage flowing into the river Delaware in the neighborhood of the Kensington pumping station has been ever on the increase.

The following extract is taken from the report for 1871, p. 28:

"The immense quantity of filth of every description deposited in the river from the common sewers, estimated

at over 13,000,000 gallons daily, and decomposing organic matter always floating about the wharves, which is carried up and down the river front by the tidal currents, and constantly agitated by the general traffic upon the river, must of necessity have a deleterious effect upon the water, even at a distance from the shore. * * * *In the opinion of this Board, water taken from the Delaware River at any point along the city front is totally unfit for domestic use.*"

Again, in the report of the Board of Health to the Mayor, for 1882, p. 13:

"The water pumped at the Kensington Works is unfit for domestic use, and this station should be abandoned." * * *

"This recommendation has frequently been made before, but it has never been heeded. It would appear reasonable to infer that the high death rate in the wards supplied with this water has some connection with the fact above stated."

From the report of Chief Engineer, Philadelphia Water Department, for 1883, p. 45:

"The Delaware, along the city front, is the recipient sooner or later, of the sewage refuse and street washings of a city area occupied by a population probably exceeding 800,000. These waste matters are borne up and down by the tides and usually pass and repass the city several times before taking their final departure. Under these circumstances, whatever may be the volume of the stream, it is by necessity polluted and is not suitable for immediate and habitual daily use.

"*In especial is the vicinity of the Kensington station marked by an accumulation of the foulest materials.*

"Its central position insures its getting the full benefit of the city's sewage, and in addition the Aramingo Canal—an open sewer of large dimensions and choked with filth—discharges in its immediate vicinity. The water taken thence is utterly unfit for human consumption."

These extracts might be indefinitely multiplied, chemical analyses might be quoted, health statistics dwelt upon—but to what purpose? The evidence I have already

presented seems to me so overwhelming that it would gain nothing in force by such additional arguments.

If the arguments against the Kensington station carried only one-tenth of the weight of those actually existing, there would still be sufficient reason to require its immediate removal.

The existence of the Kensington station through the past thirty years has been a sufficient disgrace to the city. Let it be tolerated no longer. Let public opinion express itself strongly, unmistakably. Let the newspapers of this city unceasingly agitate the matter. Let the learned and other societies engage in the contest. Let individual influence be exercised. The Kensington pumping station will then exist only as a memory of the past, to be long remembered for the desolation it has wrought in many families, but not to be feared for that which it also threatens, as at the present time and in the future.

Let us not be satisfied with any half measures, for so long as the Kensington pump remains it will be liable to be put into operation at any time. The station must be completely dismantled and pumping rendered absolutely impossible in the future.

Finally, let me ask you gentlemen, who represent the most prominent of the chemists of this city, and who by your attainments and knowledge are especially qualified to give judgment on this most important subject, unanimously to recommend to the INSTITUTE the passage of the following resolution:

"That the FRANKLIN INSTITUTE most strongly condemns the use of the Delaware water at Kensington for city supply and that it urges Councils to take immediate steps to render possible the abandonment of the Kensington pumping station."

By passing this resolution without a dissenting vote, I feel that you will confer a great benefit on the city and add to the good work for which the FRANKLIN INSTITUTE has been noted in the past.

ABSTRACTS.

ALLOTROPIC FORMS OF SILVER. BY M. CAREY LEA.—In the *American Journal of Science* for June, 1889, Mr. M. Carey Lea has a paper on "Allotropic Forms of Silver." His experiments show that metallic silver may exist in a perfectly soluble form, dissolving easily and abundantly in water. Starting from this, it may show all degrees of solubility down to absolute insolubility, still, however, existing in an allotropic form and quite distinct from normal or ordinary silver. The solutions formed are as perfect as those of any other soluble substance.

There are three modifications of this allotropic form:

A. The Soluble Form.—A solution of ferrous citrate (or of a mixture of ferrous sulphate and sodic citrate) is added to a solution of silver nitrate, the mixture well stirred and allowed to stand for ten or fifteen minutes. The lilac-blue precipitate is then washed on a filter with a five per cent. or ten per cent. solution of nitrate, citrate or sulphate of ammonia or of soda, in any of which salts it is perfectly insoluble. The color changes on washing to a deep blue. To remove the iron as far as possible, repeated solution in water and re-precipitation by ammonic nitrate is necessary, the ammonia salt being finally displaced by washing with ninety-five per cent. alcohol. The aqueous solution of this allotropic form of silver is blood-red. Optical examination proved it to be a true solution, and not a mere suspension of a finely-divided precipitate. "The inference, therefore, seems to be very strong that there exists an allotropic form of silver, freely soluble in water. This is a property so exceptional in a metal that I have admitted it with much hesitation. The principal arguments are as follows:

"The contents of silver in the various products was very carefully, and, I believe I may say, quite accurately determined; it was extremely high, always above ninety-seven per cent. As already remarked, this virtually excludes the presence of all other elements, except hydrogen and possibly oxygen. These elements were carefully searched for, but their presence could not be detected. To suppose that we had to do with a mixture in which some compound of silver was mixed with metallic silver was not possible, for, as the whole was soluble, we should still have to admit the solubility of silver.

"We have, consequently, to deal with a substance containing over ninety-seven per cent. of silver, and neither hydrogen nor oxygen in combination with it—the remaining two or three per cent. fully accounted for by ferric oxide and citric acid, determined as present as accidental impurity; the substance itself readily amalgamating with mercury by simple friction, nevertheless abundantly soluble in water. If I had been able to find any other explanation for these facts, without admitting the solubility of silver, I should have adopted it. But none presented itself.

"Whether, in solution, it exists as a hydrate—that is, in more intimate combination with one or more equivalents of water—cannot be said with entire certainty; but the easy amalgamation with mercury seems hardly to favor that view."

B. The Insoluble Form.—The first and soluble modification of the allotropic form of silver was produced, as shown above, by precipitating by an alkaline nitrate, citrate or sulphate. The second and insoluble form is produced by precipitating by magnesium, cupric, ferrous or nickel sulphate, or by potassium bichromate or ferrocyanide, or by barium nitrate, or even by silver nitrate. If any one of these salts is employed in extremely dilute solutions as the precipitant, the resulting precipitate is insoluble in water. If it is treated with a concentrated solution of any of the above salts, it becomes, strange to say, once more soluble in water.

This insoluble form is best seen when applied as a thin film to paper by a brush, enough water being added to give it a paste-like consistency. This film is of a greenish color, blue in certain lights, yellow in others ; the yellow being the more pronounced in proportion as the washing is thorough. On drying, the lustre is remarkable, a perfect mirror being obtained. This insoluble form, after drying at 100°C., contained 97·96 per cent. silver. "The remaining 2·04 per cent. consisted of ferric oxide and citric acid."

C. The gold-yellow and copper-colored silver is produced by the reduction of silver tartrate by ferrous tartrate. The resulting precipitate is first glittering red, then changes to black, and on the filter has a beautiful bronze appearance. The silver nitrate is entirely converted into this allotropic form, which is insoluble in water, and dries to lumps exactly resembling highly-polished gold. A paste of it extended over glazed paper, dries with the splendid lustre of gold leaf. The percentage of silver present = 98·75. Occasionally, a spontaneous reversion to normal silver occurs, the latter being extremely beautiful and resembling the finest frosted jeweler's silver.

All of the above allotropic forms have the following properties in common :

(1) *That of drying with their particles in optical contact* and consequently forming films and mirrors as above described.

(2) *The halogen reaction.* When any of the films on paper are dipped in a solution of sodium hypochlorite of ferric chloride, or of iodine dissolved in potassium iodide, magnificent intense shades with metallic reflections are produced. They often remind one of the color of a peacock's tail and are caused by interference. This characteristic forms one of the principal reactions for distinguishing allotropic silver from ordinary silver.

(3) The stronger acids, even when much diluted, instantly convert the allotropic form of silver into normal gray silver, without the slightest evolution of gas.

(4) All of these allotropic forms are easily reduced to an impalpable powder. In addition to these four points, Mr. Lea states that all of his products readily form an amalgam with mercury.

Mr. Lea has been at work upon this subject for over three years. He expects to have a second paper in the July number of the *American Journal of Science.* The properties of these allotropic forms of silver discovered by him are certainly extraordinary. Indeed, any *one* of the properties of these products is remarkable. It is remarkable that silver can be obtained in a form having all the color and brilliancy of gold. It is remarkable that while having thus the lustre of a metal and also the metallic property of amalga-

mating with mercury, it still is friable and easily reduced to powder. But most remarkable of all is the fact that it is freely and abundantly soluble in water. Certainly this property is unique. In the entire list of metals there is none that possesses anything like it.

Mr. Lea's investigations have opened a most interesting field of research, that will probably produce results of the highest importance. P.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Allentown, Pa. Fourteenth Annual Report of the Water Commissioners for 1888. From the Commissioners.

American Institute of Electrical Engineers. Transactions. Vol. 5. From the Institute.

American Institute of Mining Engineers:

Hague. Soaping Geysers.

Goodale. The Occurrence and Treatment of the Argentiferous Manganese Ores of Tombstone District, Arizona.

Dewey. Note on the Nickel Ore of Russell Springs, Logan County, Kansas.

Leggett. Notes on the Rosario Mine, Honduras, C. A.

Browne. The Distribution of Phosphorus in the Ludington Mine, Iron Mountain, Michigan: A Study in Isochemic Lines.

Munroe. The English *versus* the Continental System of Jigging—Is Close Sizing Advantageous?

Munroe. The new Dressing-Works of the St. Joseph Lead Company, at Bonne Terre, Missouri.

Claghorn. Notes on the Bernice Anthracite Coal Basin, Sullivan County, Pa.

Carpenter. Note on the Influence of Columbite upon the Tin Assay.

Hunt. Note upon the Modification of the Reducing Process Used by the Carbon Iron Company.

Wainwright. A New System for Operating Regenerative Hot-Blast Stoves.

Birkinbine. Prominent Sources of Iron Ore Supply.

Catalogue of Officers, Members, Rules, &c., to June 1st, 1889. From the Institute.

Badt, F. B. Bell-Hangers' Hand-Book.

Dynamo Tenders' Hand-Book. From Electrician Publishing Co.

Binghamton, N. Y. Annual Report of the Water Commissioners for the year 1888. From the Commissioners.

Blair, A. A. The Chemical Analysis of Iron. From the Author.

Board of Commissioners of Public Charities. Nineteenth Annual Report for 1888. From the Board.

Boston Public Library. Thirty-seventh Annual Report of the Trustees of the Public Library. From the Library.

British Association for the Advancement of Science. Report of the Fifty-eighth meeting. From the Association.

Brooklyn Library. Thirty-first Annual Report. From the Librarian.

Buffalo Historical Society. Annual Report of the Board of Managers. From the Society.

Canadian Institute. Thirty-ninth Annual Report. From the Institute.

Canadian Society of Civil Engineers. Transactions. Vol. 2. Part 1. From the Society.

Commercial Exchange. Thirty-fifth Annual Report. From the Secretary.

Connecticut Board of Agriculture. Twenty-second Annual Report of the Secretary. From the Secretary.

Cooper Union. Thirtieth Annual Report. From the Trustees.

Cousins, Robert H. A Theoretical and Practical Treatise on the Strength of Beams and Columns. From the Author.

Cundill, J. P. A Dictionary of Explosives. From Royal Engineers' Institute.

Department of Public Instruction, Chicago. Thirty fourth Annual Report. From the Department.

Engineers' Society of Western Pennsylvania. Proceedings of Meeting, April 16, 1889. From the Society.

Geological Survey of New Jersey. Annual Report of the State Geologist for 1888. From Prof. G. H. Cook.

Gemeinfassliche Darstellung des Eisenhüttenwesens. From the Verein Deutscher Eisenhüttenleute.

Germanischer Lloyd. Dritter Nachtrag. Internationales Register, 1889. From Lars Westergaard.

Green, Henry J. Catalogue of Scientific Instruments. From Francis Leclere.

Guatemala. Informe de la Direccion General de Estadistica, 1888. From the Director-General.

Hofman, A. W. Bericht über die Entwickelung der chemischen Industrie. From Reuben Haines.

India. Account of the Operations of the Great Trigonometrical Survey. Vol. 10. From the Viceroy and Governor-General of India.

James, Bushrod W. American Resorts, with Notes upon their Climate. From the Author.

Kansas State Board of Agriculture. Report, for April, 1889. Report, Quarter ending March 31, 1889. From the Board.

Kansas State Board of Health. Fourth Annual Report. From the Board.

Knudson-Ellsworth Telephone. Description, testimonials, etc.
From T. G. Ellsworth.

Kunz, Geo. F. A Collection of Precious and Ornamental Stones of North America, exhibited at the Paris Exposition.
Meteoric Iron from Arkansas.
Mineralogical Notes.
On Two New Masses of Meteoric Iron.
Precious Stones.
Precious Stones, Gems and Decorative Stones in Canada and British America.
From the Author.

Lamb, Robert W. Our Twin Cities. From Louis E. Levy.

Lewiston Water Board. Ninth Annual Report. From the Board.

Literary and Historical Society of Quebec. Transactions. No. 19.
From the Society.

Manchester Association of Engineers. Thirty-third Annual Report of the Council.
Accuracy in Mechanical Construction.
The Forth Bridge.
A New Chapter in the History of the Manchester and Liverpool Railroad.
Some Types of the Modern Locomotive.
From the Association.

Massachusetts Agricultural Experiment Station. Analysis of Commercial Fertilizers. April, 1889. From the Station.

Meteorological Council, London:
Hourly Readings. Part 3. 1886.
Weekly Weather Reports. January 7 to May 9, 1889.
Report of the Fourth Meeting of the International Meteorological Committee. From the Council.

Michigan. Proceedings and Addresses at a Sanitary Convention held at Hastings, December, 1888.
From the State Board of Health.

New Bedford, Mass. Tenth Annual Report of the Board of Health.
From the Board.

New Jersey Geological Survey. Atlas Sheet No. 20.
From the State Geologist.

New Jersey State Agricultural Experiment Station. Ninth Annual Report.
From the Director.

New Orleans Water Works Company. Eleventh Annual Report.
From the Company.

New York Board of Railroad Commissioners. Sixteenth Annual Report.
From the Board.

New York Meteorological Observatory. Reports for January, February, March and April, 1889. From the Director.

Pennsylvania Railroad Company. Forty-second Annual Report for 1888.
From the Company.

Pennsylvania State College. Annual Report for 1887.
From the College.

Pennsylvania State College Agricultural Experiment Station. Bulletin No. 7.
From the College.

Porter, N. American Colleges and the American Public.
From Reuben Haines.

Regia Accademia dei Fisiocritici di Siena. Atti. Serie 4, Vol. 1, Fas. 1 and 2.
From the Academy.

Smith's History of the Colony of Nova Cæsarea, or New Jersey.
From Reuben Haines.

Société d'Encouragement pour l'Industrie Nationale. Annuaire 1889.
From the Society.

Stevens, W. Le Conte. The Sensitive Flame as a Means of Research.
From the Author.

Trimble, Henry, and J. M. Schroeter. Oil of Camphor.
From Henry Trimble.

U. S. Department of Agriculture:

Division of Entomology. Periodical Bulletin, No. 11.
Botanical Division. Bulletin No. 10.
Report of the Statistician, No. 62.
Report of the Commissioner for 1888.
From the Department.

U. S. Department of the Interior:

Forty-Seventh Congress, First Session. Senate Misc. Docs., Vols. 7, 8 and 9.
Forty-Seventh Congress, Second Session. House Misc. Docs., Vol. 13, parts 17, 19, 21 and 22.
Forty-Eighth Congress, Second Session. Senate Ex. Docs., Vol. 2, part 2.
Forty-Eighth Congress, Second Session. House Ex. Docs., Vol. 14.
Forty-Ninth Congress, First Session. Senate Ex. Docs., Vol. 8.
Forty-Ninth Congress, First Session. Senate Misc. Docs., Vols. 1 and 6.
Forty-Ninth Congress, First Session. House Ex. Docs., Vols. 1, 4, 5, 7 to 10, 14 to 17, 19, 20, 21, 23, 25 to 28, 31, 33, 35 and 36.
Forty-Ninth Congress, First Session. House Misc. Docs., Vols. 12, 13, 15, 17 and 20.
Forty-Ninth Congress, Second Session. Senate Misc. Docs., Vol. 3.
Forty-Ninth Congress, Second Session. House Ex. Docs., Vols. 1 and 28.
Forty-Ninth Congress, Second Session. House Reports, Vol. 3.
Fiftieth Congress, First Session. Senate Journal.
Fiftieth Congress, First Session. House Journal, Vols. 1 and 2.
From the Department.

U. S. Department of State. Reports from the Consuls of the United States. March, 1889. From the Department.

U. S. Geological Survey. Atlas Sheets (28). From the Survey.

U. S. Hydrographic Office. Pilot Chart of the North Atlantic Ocean. June, 1889. From the Philadelphia Branch Office.

U. S. Patent Office. Rules of Practice. Revised March 9, 1887. From Wm. B. Cooper.

Specifications and Drawings of Patents. April, 1888. From the Office.

U. S. Signal Office. Bibliography of Meteorology. Part 1—Temperature.
List of Books and Articles in the Library of the Surgeon-General's Office. From the Signal Officer.

U. S. War Department. Regulations for the Army of the United States. 1889. From the Adjutant-General.

Waltham, Mass., City Documents. 1888. From the City Clerk.

Washington University. Catalogue of Officers and Students. From the University.

Western Mineral Wool Company. The Uses of Mineral Wool. From the Company.

Wire-Rope Tramways for Economical Transportation. From Cooper, Hewitt & Co.

Worcester Polytechnic Institute. Catalogue. 1889. From the Institute.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, June 19, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
WEDNESDAY, June 19, 1889.

JOSEPH M. WILSON, president, in the Chair.

Present, 106 members and twelve visitors.

Additions to membership since last report, thirty-four.

The Secretary reported the resignations of Mr. C. W. HOWARD, Prof. WM. D. MARKS and Mr. PEDRO G. SALOM as members of the Committee on Science and the Arts.

The resignations were accepted and a ballot was ordered, to fill the vacancies, which resulted in the election of

Dr. W. C. HEAD, in place of Mr. HOWARD.

Mr. JOHN HALL, in place of Prof. MARKS, and

Prof. ARTHUR BEARDSLEY, in place of Mr. SALOM.

Mr. WM. L. BOSWELL was appointed as a delegate to the Universal Exposition, in Paris, to report on Fire-proof Building Construction, and on Means and Appliances for Extinguishing Fires, and the President and Secretary were authorized to have prepared a suitable document certifying the fact, over their signatures and the seal of the INSTITUTE.

Dr. ROBERT GRIMSHAW, of New York, gave a description of Bailey's Improved Adjustable-Hub Pulleys, and of an improved Cotton Compress. (Referred for publication.)

Mr. T. G. ELLSWORTH, of New York, gave a description of the Knudson-Ellsworth Acoustic Telephone, exhibiting the instrument in operation. (Referred for investigation and report to the Committee on Science and the Arts.)

Mr. S. LLOYD WIEGAND gave some account of the successful use of steel spheres for reducing the friction of journals. These were made upon the Simons Rolling Machine, previously described in the JOURNAL.

Dr. S. C. HOOKER read a brief paper, condemning the use of the Delaware River water, at Kensington, as unfit, by reason of its serious contamination with sewage, for drinking, and urging the abandonment of the Kensington pumping station.

The paper embodied the accompanying resolution of the CHEMICAL SECTION, "That the FRANKLIN INSTITUTE most strongly condemns the use of the Delaware water, at Kensington, for city supply, and respectfully urges Councils to take immediate steps to render possible the abandonment of the Kensington pumping station."

The resolution was the subject of some debate, and was thereupon adopted.

Mr. W. F. JENNINGS exhibited on the screen a series of photographic views of the recent inundations along the line of the Pennsylvania Railroad, and the Secretary showed a series of views, exhibiting the destruction wrought by the deluge in the Conemaugh Valley.

Adjourned. WM. H. WAHL, *Secretary*.

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR MAY, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 31, 1889.

TEMPERATURE.

The mean temperature for May, 1889, was 62°·0, which is one degree above the average.

The warmest period of the month occurred on the 9th, and the coldest on the 2d, 4th and 29th. Frosts were general throughout the state on these dates.

The highest temperatures reported were Carlisle, 96°; Hollidaysburg, 94°; Reading, 94°; Coatesville, 94°, and York, 94°. The lowest temperatures were Emporium, 25°; New Castle, 26°; Columbus, 26°, and Dyberry, 26°.

The highest mean monthly temperatures were Indiana, 68°·3; Annville, 66°·5, and Emporium, 64°·5. The lowest were Wellsboro, 55°·1; Columbus, 56°·0, and Dyberry, 56°·3.

From January 1st to May 31st, the temperature excess was 404° at Philadelphia, 231° at Pittsburgh, and 56° at Erie.

BAROMETER.

The mean atmospheric pressure was 29·97, which is normal. The range between the extremes was about seven-tenths.

The highest noted was on the 18th, and the lowest during the 11th. Neither were attended by any unusual atmospheric conditions.

The minor depression of the 31st, accompanied the heavy rainfall on that date.

PRECIPITATION.

The average rainfall over the state during the month was 5·91 inches, which is an excess of over two inches. Had it not been for the phenomenal rainfall of the 31st, there would have been a deficiency in the western and middle portions of the state. The largest totals in inches for the month were McConnellsburg, 12·41; Grampian Hills, 11·60; Charlesville, 11·07; Harrisburg, 9·51; Smethport, 9·21, and Selins Grove, 9·20. The excessive and unprecedented rainfall of the 31st, which caused disastrous floods, was at

Grampian Hills, 8·37 inches; McConnellsburg, 7·08 inches; Charlesville, 6·71 inches; Selins Grove, 6 inches; Emporium, 5·85 inches; Smethport, 5·50 inches; Hollidaysburg, 5·12 inches, and Harrisburg, 4·66 inches. In the southeastern portion of the state the fall was very light on this date, many stations reporting less than one-tenth of an inch.

From the 1st to the 10th there was a general absence of rain. From this time to the end of the month rains occurred almost daily at some stations.

WIND AND WEATHER.

The prevailing direction of wind was from the west, and the month may be characterized as warm and moist. Frosts were general from the 1st to the 4th, inclusive, and on the 29th, all of which considerably impaired growing crops and fruits.

The first thunder storm of the month occurred on the afternoon of the 10th, and was general throughout the state. The lightning and wind caused heavy damages in several places. In some sections hail-stones of large size fell in quite large quantities. The storm was from the northwest, and its approach was heralded by great banks of ominous looking clouds, which were violently agitated. At most stations the wind was of terrific force, and carried with it blinding and stifling clouds of dust, which fairly darkened the atmosphere. At Philadelphia a velocity of seventy-two miles was registered. Fortunately the great force was of short duration. With the bursting of the storm the temperature fell from ten to twenty degrees. At Philadelphia the self-registering barometer fell rapidly from 8 A. M. From 1.30 P. M. to 4 P. M. the fall was more decided. After the storm burst at 5 P. M. it rose one-tenth instantaneously. As a *dust storm* it was phenomenal in magnitude and intensity.

On the 31st, the central portion of the state was visited by one of the greatest rainfalls and floods ever known in this country for magnitude and destructiveness. Large sections were flooded, whole towns and cities were swept away, thousands of people drowned, and millions of dollars in property destroyed. It is estimated that from six to eight inches of rain fell in twenty-four hours over a large area of the central part of the state.

Extracts from the reports of observers, May 31st:

Grampian Hills.—From 11.40 P.M. 30th to 11.20 P.M. of 31st, 8·37 inches of rain fell. Six inches of rain fell in seven hours. Most destructive flood in Anderson's Creek on record. Wind east.

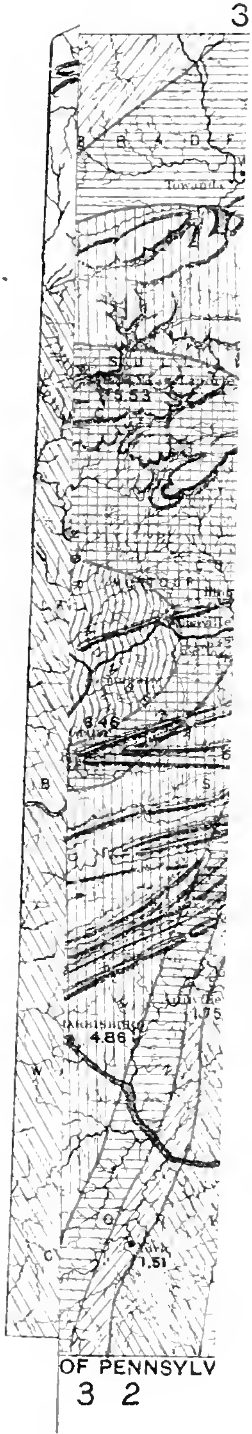
McConnellsburg.—Easterly winds. 5·45 inches of rain from 4 P.M. 30th to 4 P.M. 31st. Rain ceased midnight of 31st; 8·31 inches in thirty-two hours. Disastrous floods.

Charlesville.—South, southeast, and southwest winds. Heaviest rains in years; 6·71 inches from 9 P.M. 30th to 9 P.M. 31st. Storm began 3.15 P.M. 30th.

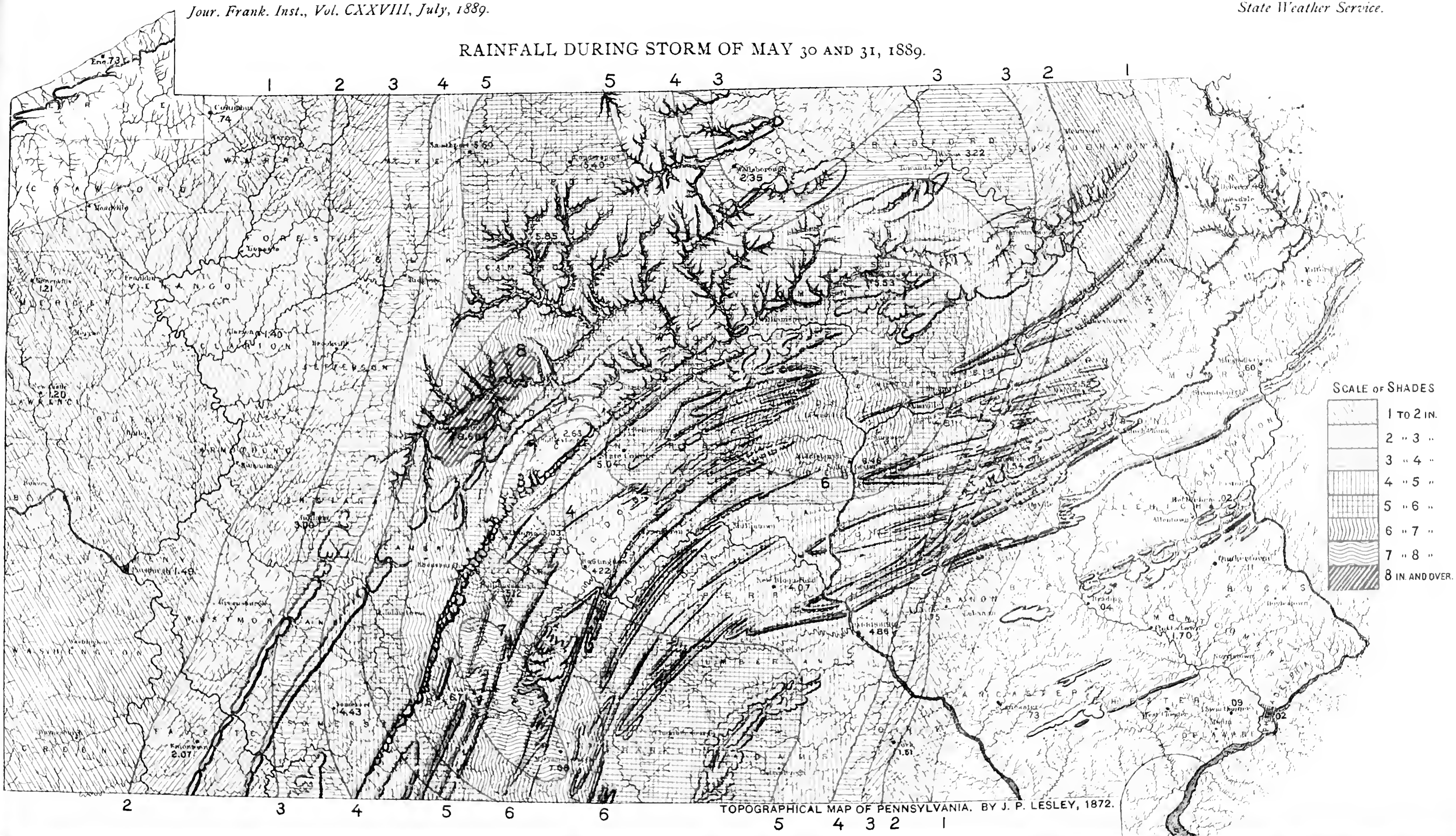
Selins Grove.—Southeast winds. Rain began 2.20 P.M. 30th; six inches of rain on 31st. Thunder in east at 3 P.M.

Harrisburg.—On the 31st and night of 1st, eight inches of rainfall in eighteen hours.

) 31, 1889.



RAINFALL DURING STORM OF MAY 30 AND 31, 1889.



ER SERVICE FOR MAY, 1889.

Precipitation. Total Inches.	Number of Days Rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction. 7 A. M.	2 P. M.	9 P. M.	Observers.
6·45	14	7	9	15	NW	NW	NW	Oscar D Stewart, Sgt. Sig. Corps.
·07	13	14	7	10	W	W	SW	Rev. A Thos. G. Apple.
·60	9	15	7	9	NW	NW	NW	C. M. Dechant, C.E.
·75	9	...	...	...	...	...	...	Dr. Charles B. Dudley.
7·43	13	14	10	7	...	...	...	Prof. J. A. Stewart
·76	10	9	6	16	NW	NW	NW	Charles Beecher.
5·70	11	14	7	10	W	W	W	J. C. Hilsman.
5·45	12	14	9	8	SW	NW	NW	J. L. Heacock.
3·04	11	12	7	12	W	W	W	T B. Lloyd
..	...	...	...	...	...	...	...	Prof. Wm. Frear.
·28	11	11	5	16	SW	SW	SW	Geo. H. Dunkle.
·78	15	14	7	10	NW	NW	SE	Jesse C. Green, D.D S.
·29	14	15	6	10	W	W	W	W. T. Gordon.
..	...	11	11	9	W	W	W	Rev. W. W. Deatrick, A.M.
·59	9	10	13	8	SW	SW	SW	C M Thomas, B.S.
·60	12	8	12	11	W	W	W	Nathan Moore.
..	...	...	...	...	...	...	...	Prof. John A. Robb.
..	...	...	...	...	...	...	...	Robert M. Graham.
..	...	...	...	...	...	...	...	R. B Derickson.
4·52	14	9	9	13	W	W	W	J. E. Pague.
9·51	12	4	19	8	W	W	W	Frank Ridgway, Sgt. Sig. Corps.
5·84	9	7	4	20	NW	NW	NW	Prof Susan J. Cunningham.
·61	14	9	11	11	SW	SW	SW	Peter Wood, Sgt Sig. Corps.
5·93	12	10	15	6	W	W	W	Wm Hunt
2·41	13	11	8	12	W	W	W	Thomas F. Sloan.
7·18	13	9	15	7	W	W	W	Prof. W. J. Swigart.
4·71	8	16	5	10	W	W	W	Prof. Albert E Maltby.
4·46	12	10	11	10	W	W	SE	A M Schmidt, A.B.
3·20	6	6	14	11	NW	NW	NW	Wm. T. Butz.
5·47	14	14	4	13	W	W	W	Wm. H. Kline.
..	...	15	7	9	...	...	...	Geo. W. Bowman, A.M , Ph.D.
..	...	...	...	...	..	...	...	H. D. Miller, M.D.
·21	8	11	10	10	S	S	S	Armstrong & Brownell.
2·57	10	5	7	19	SW	SW	SW	Prof S. H. Miller.
7·47	9	17	9	5	W	W	W	Charles Moore, D D.S.
3·12	13	10	11	10	W	W	W	Harvey Huffman.
4·30	10	17	6	8	W	W	W	Lerch & Rice.
5·06	12	11	9	11	W	W	W	Frank Mortimer.
4·32	15	8	11	12	NW	NW	NW	Luther M. Dey, Sgt. Sig Corps.
7·93	8	10	3	18	W	W	W	C. L Peck.
6·93	12	12	2	17	NW	NW	NW	E. C Wagner.
·20	10	13	8	10	NW	SE	NW	J M Boyer,
8·32	9	14	5	12	NW	NW	NW	W. M Schrock.
9·21	10	10	8	13	SW	SW	SW	E. S. Chase.
3·45	10	12	9	10	N	W	N	H. D Deming.
2·85	15	11	9	11	SW	SW	SW	Wm. Loveland.
4·72	15	10	9	12	NW	NW	NW	Theodore Day.
5·47	12	...	...	...	...	...	...	John Torrey.
5·65	10	17	7	7	NW	NW	NW	Mrs. L. H. Grenewald.

T. F. TOWNSEND, *Sergeant Signal Corps, Assistant.*

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for May, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Temperature. Maximum. Highest.	Temperature. Maximum. Date.	Temperature. Minimum. Lowest.	Temperature. Minimum. Date.	Temperature. Mean of Maximum.	Temperature. Mean of Minimum.	Temperature. Daily Range. Mean.	Temperature. Daily Range. Greatest.	Temperature. Daily Range. Date.	Temperature. Daily Range. Least.	Temperature. Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Precipitation. Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction. 7 A. M.	Wind. Prevailing Direction. 2 P. M.	Wind. Prevailing Direction. 9 P. M.	Observers.
Allegheny,[1]	Pittsburgh,	847	29.950	30.230	29.620	61.6	90.0	10	37.0	2, 4	72.2	52.5	19.7	32.0	5	4.0	31	62.5	47.8	6.45	14	7	9	15	NW	NW	NW	Oscar D. Stewart, Sgt. Sig. Corps.
Bedford,	Charlesville,	1,300	...	...	...	58.9	89.5	9	29.0	2	71.1	51.7	19.4	34.5	8	7.5	22	71.4	50.0	11.07	13	14	7	10	W	W	SW	Rev. A. Thos. G. Apple.
Berks,[1]	Reading,	304	29.989	30.314	29.704	60.5	94.0	5	32.5	3	75.3	50.1	25.2	45.0	10	6.5	27	82.6	53.3	3.60	9	15	7	9	NW	NW	NW	C. M. Dechant, C.E.
Blair,[2]	Altoona,	1,181	...	...	...	64.1	91.0	10, 18	36.0	2	74.4	54.8	19.6	29.0	18	8.0	31	55.1	48.0	4.75	9	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947	...	...	...	63.0	94.0	9	27.0	2	74.0	46.0	28.0	50.0	8	8.0	13	75.0	53.0	7.43	13	14	10	7	...	...	...	Prof. J. A. Stewart.
Bradford,	Wysox,	718	29.964	30.238	29.728	58.9	89.2	17	29.5	4, 29	71.3	46.5	24.8	44.0	5	5.5	22	74.6	50.0	1.76	10	9	6	16	NW	NW	NW	Charles Beecher.
Bucks,	Forks of Neshaminy,	...	...	...	...	62.0	87.0	10	44.0	3	...	...	...	...	...	...	...	...	...	5.70	11	14	7	10	W	W	W	J. C. Hillsman.
Bucks,	Quakertown,	536	29.980	30.330	29.660	60.7	89.5	9	30.5	3	73.2	47.9	25.3	42.5	8	8.7	27	81.0	55.1	5.45	12	14	9	8	SW	NW	NW	J. L. Heacock.
Cameron,	Emporium,	1,030	...	...	...	64.5	92.0	18	25.0	4	73.2	44.8	28.4	48.0	5	5.0	31	...	...	8.04	11	12	7	12	W	W	W	T. B. Lloyd.
Centre,	State College— Agricultural Experiment Station,	1,191	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Wm. Frear.
Centre,	Phillipsburg,	1,350	...	...	...	56.9	93.0	17	27.0	2	72.0	44.1	27.9	47.0	8	4.0	27	...	...	5.28	11	11	5	16	SW	SW	SW	Geo. H. Dunkle.
Chester,	West Chester,	455	29.958	30.345	29.657	62.4	90.0	9	38.0	2	72.2	53.6	18.6	32.0	5	5.0	20	72.0	52.5	5.78	15	14	7	10	NW	NW	SE	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	60.0	94.0	9	34.0	3	74.7	50.1	24.6	43.0	8	7.0	20	...	...	5.29	14	15	6	10	W	W	W	W. T. [illegible]
Clarion,	Rimersburg,	1,500	...	...	...	62.0	91.0	9	35.0	3	71.0	54.0	17.0	26.0	8	5.0	19	...	...	...	...	11	11	9	W	W	W	Rev. W. W. Deatrick, A. M.
Clarion,	Clarion— State Normal School,	1,530	...	...	...	58.0	86.0	10, 18	28.0	2	66.2	43.6	22.6	44.0	15	7.0	10	72.0	49.0	4.59	9	10	13	8	SW	SW	SW	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	...	...	...	59.6	90.0	9, 17	30.0	2, 29	70.6	49.8	20.8	38.0	6	4.0	31	...	...	11.60	12	8	12	11	W	W	W	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. John A. Robb.
Columbia,	Catawissa,	491	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Robert M. Graham.
Crawford,	Meadville— Allegheny College,	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. B. Derickson.
Cumberland,	Carlisle,	480	...	...	...	63.4	96.0	8	36.0	4	74.7	56.4	18.3	34.0	9	3.0	26	74.5	57.3	4.52	14	9	9	13	W	W	W	J. E. Pague.
Dauphin,[1]	Harrisburg,	361	29.984	30.350	29.350	61.5	90.0	9, 10	40.0	4	71.9	53.5	18.4	35.0	8	5.0	27	72.0	51.6	3.51	12	4	19	8	W	W	W	Frank Ridgway, Sgt. Sig. Corps.
Delaware,	Swarthmore— Swarthmore College,	190	29.958	30.324	29.676	62.3	89.9	10	37.5	22	76.0	51.1	24.9	36.6	30	6.5	27	87.0	58.0	5.84	9	7	4	20	NW	NW	NW	Prof. Susan J. Cunningham.
Erie,[1]	Erie,	681	29.960	30.210	29.610	58.0	89.0	18	35.0	29	65.0	50.0	15.0	29.0	30	4.0	21	69.0	47.0	2.61	14	9	11	11	SW	SW	SW	Peter W[illegible], Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	29.966	30.222	29.750	60.9	88.0	10	30.0	4	71.6	48.4	23.2	39.0	6	5.0	22	70.0	50.5	6.93	12	10	15	6	W	W	W	Wm. Hunt.
Fulton,	McConnellsburg,	875	...	...	...	62.1	93.0	9	31.0	2	73.4	48.9	24.5	44.0	8	6.0	31	74.0	52.1	12.41	13	11	8	12	W	W	W	Thomas F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650	...	...	...	60.7	93.0	17, 18	28.0	2	71.4	46.0	25.4	46.0	8	3.0	22	...	...	7.18	13	9	15	7	W	W	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	68.3	85.0	25	40.0	3	79.2	58.0	21.2	41.0	3	19.0	8	81.0	62.0	4.71	8	16	5	10	W	W	W	Prof. Albert E. Maltby.
Lancaster,	Lancaster— Franklin and Marshall College,	413	29.976	30.281	29.708	62.5	91.0	9	36.0	2	72.9	46.0	26.9	38.5	8	7.0	27	82.6	57.1	4.46	12	10	11	10	W	W	SE	A. M. Schmidt, A. B.
Lawrence,	New Castle,	932	...	...	...	61.8	90.0	9, 17	26.0	2	71.5	44.7	26.8	45.0	6	11.0	10	...	...	3.20	6	6	14	11	NW	NW	NW	Wm. T. B[illegible]
Lebanon,	Myerstown,	474	29.939	30.262	29.741	60.4	93.9	9	32.6	2	74.8	50.4	24.4	41.8	8	7.2	27	83.6	55.8	5.47	14	14	4	13	W	W	W	Wm. H. Kline.
Lebanon,	Annville— Lebanon Valley College,	339	...	...	...	66.5	...	...	...	...	...	...	...	...	...	...	...	77.2	61.2	...	...	15	7	9	...	...	...	Geo. W. Bowman, A. M., Ph. D.
Luzerne,	Drifton— Drifton Hospital,	1,655	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H. D. Miller, M. D.
McKean,	Smethport,	1,500	...	...	...	57.4	89.5	18	27.0	4	69.3	44.1	25.2	44.5	8	7.5	2	...	...	9.21	8	11	10	10	S	S	S	Armstrong & Brownell.
Mercer,[1]	Greenville— Thiel College,	1,000	29.865	30.138	29.569	56.3	87.4	10	27.0	2	70.8	44.4	36.4	39.5	5	8.0	31	84.9	49.8	2.57	10	5	7	19	SW	SW	SW	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	...	...	...	63.0	91.0	10	30.0	3	74.3	55.3	19.0	35.0	7	...	27	75.0	53.0	7.47	9	17	9	5	W	W	W	Charles Moore, D. D. S.
Monroe,	Marshall's Creek,	520	...	...	...	58.7	75.1	17	42.1	2	...	...	...	...	...	...	...	73.5	55.5	3.12	13	10	11	10	W	W	W	Harvey Huffman.
Northampton,	Bethlehem,	360	...	...	...	64.0	92.0	9	34.0	4	74.0	51.0	23.0	45.0	6	8.0	27	66.0	52.0	4.30	10	17	6	8	W	W	W	Lerch & Rice.
Perry,	New Bloomfield,	400	...	...	...	62.1	93.0	9	29.0	4	74.6	46.3	28.3	48.0	6	6.0	31	...	...	6.06	12	11	9	11	W	W	W	Frank Mortimer.
Philadelphia,[1]	Philadelphia,	117	29.982	30.380	29.650	63.0	90.0	9, 10	43.0	2, 3	74.1	55.3	18.8	33.0	9	4.0	27	71.4	53.0	4.32	15	8	11	12	NW	NW	NW	Luther M. Dey, Sgt. Sig. Corps.
Potter,	Coudersport,	1,670	...	...	...	59.7	90.0	17	26.0	29	69.4	44.5	24.9	46.0	8	7.0	3	78.9	52.3	7.90	8	10	3	18	W	W	W	C. L. Peck.
Schuylkill,	Girardville,	1,000	29.964	30.314	29.609	60.0	89.0	9	33.0	2	70.7	49.3	21.4	40.0	5	7.0	20	...	...	6.93	12	12	2	17	NW	NW	NW	E. C. Wagner.
Snyder,	Selins Grove,	445	...	...	...	63.2	92.0	9, 10	40.0	3, 4	71.3	55.2	16.1	36.0	5	4.0	27	...	...	9.20	10	13	8	10	NW	SE	NW	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	54.2	92.0	17	28.0	2	68.3	44.6	23.7	44.0	7	11.0	25	...	...	8.32	9	14	5	12	NW	NW	NW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	...	...	...	57.3	86.0	10	31.0	2	64.7	48.7	16.0	27.0	29	3.0	21	70.0	47.5	9.21	10	10	8	13	SW	SW	SW	E. S. Chase.
Tioga,	Wellsboro,	1,327	29.932	30.258	29.622	55.1	90.0	17	30.0	29	78.9	67.2	11.7	20.0	...	5.2	...	78.9	42.3	3.45	10	12	9	10	N	W	N	H. D. Deming.
Warren,	Columbus,	1,410	...	...	...	56.0	92.0	17, 18	26.0	1, 29	68.9	43.3	25.6	48.0	8	3.0	21	75.0	47.0	2.85	15	11	9	11	SW	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	56.3	88.0	9	26.0	4	69.3	44.4	24.9	44.0	6	3.0	27	...	...	4.72	15	10	9	12	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	56.4	83.0	17	28.0	4	67.5	45.2	22.3	38.0	5	4.0	27	...	...	5.47	12	...	...	...	...	...	...	John Torrey.
York,[1]	York,	385	29.977	30.216	29.728	63.2	94.0	9	35.0	2, 4	74.9	30.9	44.0	42.0	5	9.5	27	70.0	52.5	5.65	10	17	7	7	NW	NW	NW	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

	Erie.	Greenville.	New Castle.	Honesdale.	Quakertown.	Swarthmore.	Philadelphia.	Coudersport.	Scisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Nesham'y.	Germantown.	Point Pleasant.	Dyberry.	Clarion.	York.	Marshall's Creek.	Smethport.
1	. .	. .	3	. .	. .	. .	·01	. .	. .	. .	. .	. .	·03	. .	·01	. .	. .	. .	. .	. .	. .	. .
2	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	·01	. .	. .	. .	. .	. .	. .	·20	. .	. .	. .	. .	. .	. .	. .	. .	. .	·15	. .	·01	. .	. .
4	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
5	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
6	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
7	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
8	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·84	. .	. .	. .
9	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
10	·26	·20	1·00	1·07	·64	. .	·02	·50	·62	·25	·60	·63	·45	·22	·31	·02	·62	·30	. .	·05	·12	·33
11	. .	·14	. .	·02	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·08	. .	. .	. .	. .
12	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·0[illegible]	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·60
13	·02	. .	3	·95	·12	. .	·02	·80	. .	·05	·1[illegible]		·05	·20	. .	. .	. .	. .	·55	. .	·35	·22
14	·07	·20	·58	·22	·33	·01	·09	·30	·41	. .	·2[illegible]	·25	·54	. .	1·02	·21	·21	·87	. .	·41	·12	. .
15	. .	. .	1	. .	. .	·11	·19	. .	. .	·36	. .	. .	. .	·85	. .	·22	. .	. .	. .	. .	. .	. .
16	·12	·02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
17	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
18	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
19	·29	. .	·24	·60	·35	. .	·02	. .	. .	. .	·35	. .	. .	. .	. .	. .	. .	. .	·83	. .	. .	. .
20	·30	. .	3	·95	1·43	1·59	1·25	·30	2·04	·57	1·08	2·21	2·04	·87	2·12	. .	. .	1·40	. .	1·45	·63	·70
21	·06	·13	. .	. .	·75	·04	·23	. .	·03	1·34	·38	·18	·28	·30	·09	2·28	2·70	·56	·05	·28	·12	·72
22	. .	·06	·11	. .	·10	·19	·11	·20	. .	·60	·20	·05	·09	·75	. .	. .	·13	. .	·06	·05	. .	·50
23	. .	·02	9	. .	. .	1·16	·17	. .	. .	·02	. .	. .	·04	. .	·11	·35	. .	. .	. .	. .	. .	. .
24	. .	. .	. .	·20	. .	. .	. .	. .	. .	. .	. .	. .	·16		. .	. .	. .	·03	. .	. .	. .	. .
25	. .	. .	6	. .		. .	. .	. .	. .	·04	·47	. .	. .	. .	·01	. .	. .	. .	·15	. .	. .	. .
26	. .	. .	3	·22	·52	1·20	1·18	. .	·48	·50	·19	·50	. .	·59	·87	. .	·50	·21	. .	·81	·33	. .
27	·67	·59	·04	·50	1·06	1·36	1·00	·20	·96	·01	·70	·85	·94	·57	1·00	2·14	. .	·57	·56	1·08	·85	·55
28	·01	. .	. .	. .	·03	. .	·01		. .	. .	. .	. .	. .	. .	. .	. .	·90	. .	·15	. .	. .	. .
29	·06	. .	. .	. .	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
30	·32	·68	1	·07		.	·01	. .	. .	·01	·05	·05	·20	. .	·06	.	·05	·11	. .	·02	·10	. .
31	·41	·53	1·2[illegible]	·50	·11	·09	·01	5·40	. .	.	·49	. .	. .	.	·10	·51	·46	·35	1·40	1·49	·50	5·50
	2·51	2·57	3·20	5·47	5·45	5·84	4·32	7·00	4·54	4·65	5·85	4·75	4·82	4·35	5·70	5·73	5·59	4·72	4·59	5·65	3·12	9·21

T. F. T.

PRECIPITATION FOR MAY, 1889.

Day	Erie.	Greenville	New Castle.	Columbus.	Pittsburgh.	Uniontown.	Indiana.	Somerset.	Grampian Hills.	Emporium	Phillipsburg.	Huntingdon.	Hollidaysburg.	Altoona.	Charlesville.	McConnellsburg.	Lock Haven.	New Bloomfield.
1																		
2	[illegible]																	
3	·01			·05	·01													
4																		
5																		
6																		
7																		
8																		
9							·15											
10	[illegible]	·20	1·05	·37	·63	·93	·06	·50	·40	·44			·33		·50	·17		·18
11		·14		·11	2·27	·60		1·20	·48	·05	·87	·45	·31	·50	·80	·52		
12				·24														
13	·02			·01	·45	·41		·65	·34	·40	·34	·56	·65	·38	·98	·92		·20
14	[illegible]	·20	·52		·35	·05	·10	·05	·31	·09	·24	·32	·02	·25	·15	·63		
15					[illegible]													·15
16	·12	·02		·12			·12					·01						
17							·08											
18																		
19	·29		·25	·57	[illegible]	1·94		·36	·46	·50			·06		·06			
20	[illegible]				[illegible]	·03		·10		·06	·05	·16	·04	·08	·22	·33		·25
21	[illegible]	·13		·13	[illegible]	·26			·05		·02	·06	·02		·01	·05		·10
22		[illegible]	·15	·03	·52	·24		·54	·11		·08	·07	·07		·20	·12		·04
23		·02		·03						·04	·28	·03		·08		·07		
24					·47	·10		·31	·21			·24						
25						·21		·20	·22		·17		·04		·40	·12		·16
26				·06	·03					·25	·25	·46	·20	·18	·15	·50		·44
27	[illegible]	·59	·03	·47	·04	[illegible]			·07	·15		·30	·18	·13	·28	·67		·44
28	[illegible]			·01					·35		·15			·12				·03
29	[illegible]						1·20											
30	[illegible]	·63		·07	·28		2·00		·23	·12		·60	·39		·61	1·23		·37
31	[illegible]	·53	1·20	·74	1·21	2·07	1·00	4·43	8·37	5·85	2·83	4·22	5·12	3·03	6·71	7·08		3·70
	[illegible]	[illegible]	3·20	2·83	6·45	6·93	4·71	8·32	11·60	8·04	5·28	7·18	7·43	4·75	11·07	12·41	. .	6·06

Day	Carlisle.	Wellsboro.	Harrisburg.	Selins Grove.	Wysox.	Eagles Mere.	Catawissa.	Girardville.	Meyerstown.	Lancaster.	Drifton.	Reading.	Bethlehem.	Pottstown.	West Chester.	Kennett Square.	Coatesville.	Honesdale.
1															·03		·03	
2		·10			·16													
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10		·10	·10	·16	·19	·04		1·01	·25				·42		·08	·02	·10	1·07
11	·15													·20	·02			·02
12			·34															
13	·45	·14	·83	·70	·16	·25		1·05	·25	·10		·24	·16	·10	·03	·02	·03	·95
14	·47	·05			·20	·42		·39	·43	·51		·24	·07	·62	·60	·17	·63	·22
15	·05								·01						·06	·15	·01	
16																		
17																		
18																		
19			·17		·11	·56		·48	·19	·19		·23	·64	1·25	·29	·17	·34	·60
20	·15	·15	1·55	·90	·38	·96		1·03	·94	·78		·60	1·54	1·50	1·76	1·04	[illegible]	·95
21	·03	·08	·21	·09	·07	·82		·20	·06	·38			·05	·20	·46	·24	[illegible]	
22	·04		·08	·15		·15		·07	·14	·13		[illegible]	·02		·06	·02	·01	
23	·05								·01	·11					·15		·19	
24																		·20
25	·05		·23					·07	·07	·03		·20	·36	·60	·03		[illegible]	
26	·70	·36	·32	·27				·18	·34	·67		[illegible]			1·28	1·32	[illegible]	·22
27	·78	·12	·82	·47	·27	·48		·91	1·02	·83		1·50	1·02	1·30	·01		·84	·50
28	·15								·01						·03	·02		
29																		
30	·05	·65	·20	·46	·32	·36		·61	·67	·23						·01	·01	·07
31	1·40	1·70	4·66	6·00	2·90	5·17		·93	1·08	·50		·04	·02	1·70				·50
	4·52	3·45	9·51	9·20	4·76	9·21	. .	6·93	5·47	4·46	. .	3·60	4·30	7·47	5·78	3·18	5·29	5·47

Day	Quakertown.	Swarthmore.	Philadelphia.	Coudersport.	Scisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Neshamiy.	Germantown.	Point Pleasant.	Dyberry.	Clarion.	York.	Marshall's Creek.	Smethport.
1			·01						·03		·01							
2																		
3				·20										·15		·02		
4																		
5																		
6																		
7																		
8															·84			
9																		
10	·64		·02	·50	·62	·25	·60	·63	·45	·22	·31	·02	·62	·35		·05	·12	·33
11	·01													·08				
12							·05											·60
13	·12		·02	·80		·05	·12		·05	·20					·55		·35	·22
14	·33	·01	·09	·30	·41		·28	·25	·54		1·02	·21	·21	·87		[illegible]	[illegible]	
15		·11	·19			·36				·85		·22						
16																		
17																		
18																		
19	·35		·02				·35								·83			
20	1·43	1·59	1·25	·30	2·04	·57	1·98	2·21	2·04	·87	2·12			1·40		1·45	[illegible]	[illegible]
21	·75	·04	·23		·03	1·34	·38	·18	·28	·30	·09	2·28	2·70	·56	·05	[illegible]	·22	[illegible]
22	·10	·19	·11	·20		·60	·20	·08	·09	·75			·15		·06	·05		[illegible]
23		1·16	·17			·02			·04		·11	·35						
24									·16					·03				
25						·04	·47				·01				·15			
26	·52	1·20	1·18		·48	·50	·19	[illegible]		·59	·87		[illegible]	[illegible]		[illegible]	[illegible]	
27	1·06	1·36	1·00	·20	·96	·91	·70	·85	·94	·57	1·00	2·14		[illegible]	·56	[illegible]	[illegible]	·33
28	·03		·01										·90		·15			
29																		
30			·01			·01	·05	·05	·20		·06		·05	·11		[illegible]	·10	
31	·11	·09	·01	5·40			·48				·10	·51	·46	·35	1·40	[illegible]	[illegible]	[illegible]
	5·45	5·84	4·32	7·90	4·54	4·65	5·85	4·75	4·82	4·35	5·70	5·73	5·59	4·72	4·59	5·65	5·12	5·21

T. F. T.

Emporium.—Rain began 9 P.M. 30th, ended 11.20 P.M. 31st. Total rainfall, 5·85 inches. Water twelve feet above low-water mark, and from two to three feet higher than flood of 1861.

Smethport.—Southeast winds. Rain from 11 P.M. 30th to 11 P.M. 31st. Total rainfall, 5·50 inches.

Hollidaysburg.—Strong southerly winds until about 4 P.M., then veered a little easterly and gradually subsiding. Measurements of rainfall by rain gauge, May 30th, from 4 P.M. to 9 P.M., ·39 inches; to 7 A.M. 31st, 2·11 inches; to 12 M., 3·49 inches; to 5.30 P.M. 4·23 inches; to 7 P.M. 4·97 inches; to 9 P.M., 5·51 inches; to 7 A.M. June 1st, 6·10 inches. Strong northwest wind at midnight, 31st.

Huntingdon.—The flood of history in the Juniata Valley. Water higher than ever before known; 5·41 inches of rain fell from 7 A.M. 31st to 2 A.M. June 1st; 6·57 inches from 4 P.M. 30th to 2 A.M. June 1st. Winds east and southwest.

York.—High winds from southwest; 3·19 inches of rain from early morn of 31st to early morn of June 1st. Crops badly damaged.

Carlisle.—Rain gauge overflowed. Growing grain injured. Heavy wash-outs and bridges washed away. Water higher than ever known. Southeast winds.

New Bloomfield.—Terrible rain, with thunder. East winds. Rainfall, 3·82 inches.

Annville.—A continued succession of cloud bursts. Strong southeast winds. Occasional thunder.

Quakertown.—A peculiar storm. Strong southeast winds. Upper clouds nearly stationary. Dark and threatening lower clouds, moving rapidly from south. Very little rain.

Coudersport.—Rain began 5 P.M. 30th, ended morning of June 1st. Total rainfall, 5·40 inches; highest water ever known in this section. Great damage done in Potter County. Wind south.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Charlesville, 10th, 14th, 20th; Reading, 10th, 14th; Hollidaysburg, 10th, 24th, 27th; Wysox, 14th, 31st; Falls of Neshaminy, 14th, 21st; Quakertown, 10th, 14th, 21st; Emporium, 10th, 14th; Phillipsburg, 10th; West Chester, 10th, 14th, 21st; Coatesville, 10th, 14th, 21st; Clarion, 10th; Grampian Hills, 10th, 27th; Carlisle, 10th, 13th, 15th; Harrisburg, 10th, 14th, 21st; Uniontown, 10th, 19th, 30th; McConnellsburg, 13th, 30th; Lancaster, 13th, 14th, 21st; New Castle, 22d; Myerstown, 10th, 27th, 30th; Greenville, 10th, 14th, 16th, 27th; Bethlehem, 10th; New Bloomfield, 10th, 21st, 31st; Philadelphia, 10th, 14th, 21st; Girardville, 10th, 21st, 30th; Selins Grove, 10th, 14th, 21st, 29th, 31st; Somerset, 10th, 13th, 19th, 27th, 31st; Wellsboro, 10th, 21st; Columbus, 10th, 16th, 19th, 27th; Dyberry, 10th, 14th, 20th, 21st; York, 10th, 12th, 21st, 31st; Marshall's Creek, 10th, 14th, 20th, 21st.

Hail.—Hollidaysburg, 10th; Quakertown, 10th; Grampian Hills, 10th, 27th; Uniontown, 10th; Lancaster, 21st; Myerstown, 14th; Greenville, 10th,

27th; New Bloomfield, 21st; Selins Grove, 10th, 21st; Somerset, 27th; Dyberry, 10th; Honesdale, 10th; York, 21st.

Frost.—Charlesville, 2d, 4th; Reading, 3d; Hollidaysburg, 1st, 2d, 4th; Wysox, 4th, 29th; Falls of Neshaminy, 3d, 4th, 5th, 6th; Quakertown, 2d, 3d, 4th, 23d, 24th, 29th; Emporium, 1st, 4th, 5th, 29th; Phillipsburg, 1st, 24th, 29th; West Chester, 2d; Coatesville, 2d, 3d; Grampian Hills, 1st, 2d, 29th; Carlisle, 2d, 4th; Uniontown, 4th; McConnellsburg, 2d, 3d, 4th, 5th; Huntingdon, 2d, 29th; New Castle, 1st, 2d, 29th; Myerstown, 2d, 3d, 4th; Greenville, 1st, 2d, 29th; Bethlehem, 4th; New Bloomfield, 2d, 4th; Girardville, 29th; Selins Grove, 1st, 2d, 3d, 4th, 5th, 28th, 29th; Somerset, 1st, 4th; Wellsboro, 1st, 2d, 3d, 4th, 5th, 6th, 9th, 29th; Columbus, 1st, 2d, 4th, 5th, 29th; Dyberry, 2d, 4th, 5th, 29th; Honesdale, 1st, 2d, 3d, 4th, 5th, 29th; York 24th; Marshall's Creek, 1st, 4th, 29th.

Coronæ.—Reading, 10th, 14th; Myerstown, 10th.

Solar Halos.—Charlesville, 1st, 2d, 6th, 7th, 16th, 24th; Wysox, 10th; Wellsboro, 6th; Dyberry, 1st, 13th, 29th.

Lunar Halos.—Reading, 10th; Coatesville, 10th; Grampian Hills, 6th; Lancaster, 10th; Somerset, 11th.

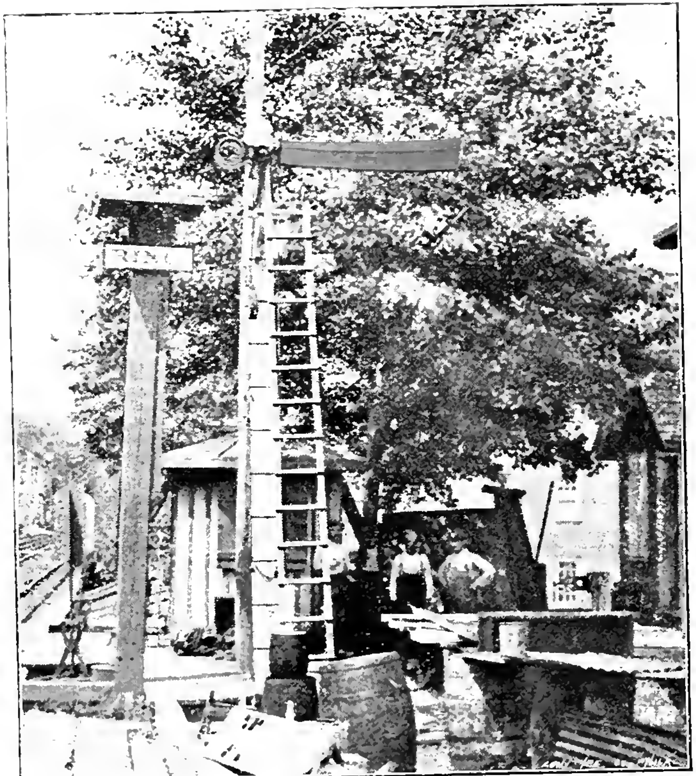
Percentage of local verifications of weather and temperature signals as reported by displaymen for May, 1889:

Weather, 83 per cent.
Temperature, 87 per cent.

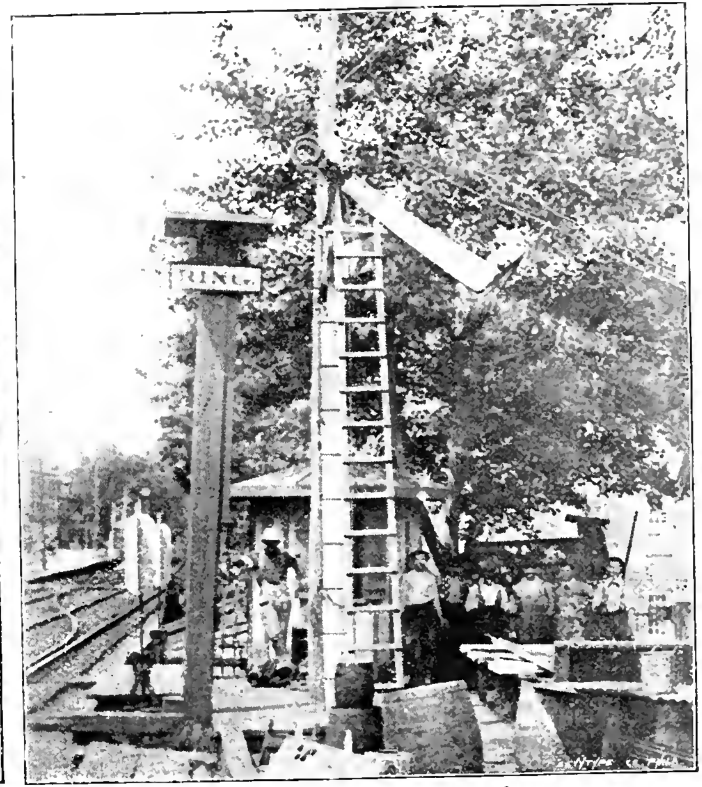
TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.

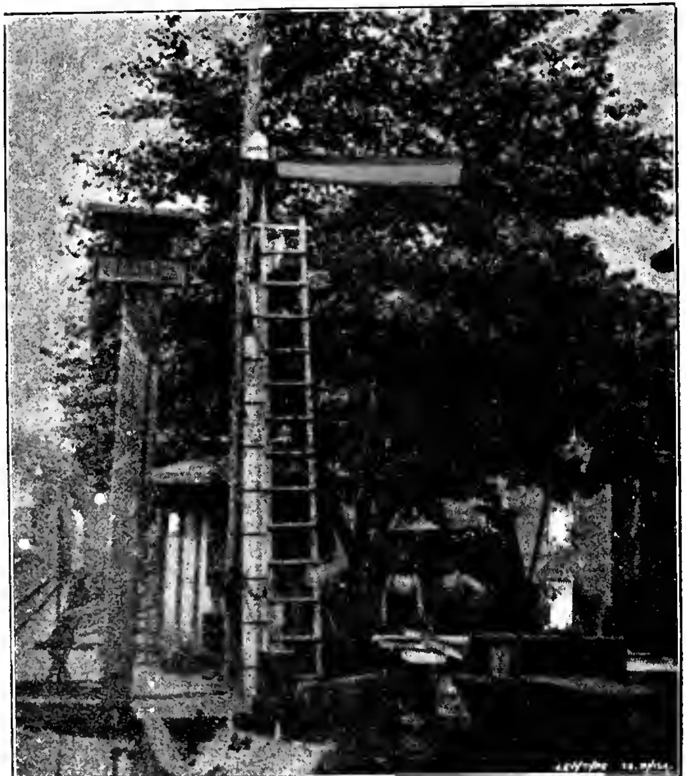
Displayman.	*Station.*
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.
W. S. Ravenscroft,	Hyndman.
R. C. Schmidt & Co.,	Belle Vernon.



Danger.—Day.



Safety.—Day.


Danger. Night


Safety. Night

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVIII. AUGUST, 1889. NO. 2.

ON KOYL'S PARABOLIC SEMAPHORE.

[*Report of the Committee on Science and the Arts.*]

[No. 1421.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 4, 1889.

Your committee, appointed to examine the system of signalling devised by Prof. C. Herschel Koyl, for use on railroads and described in the United States letters-patent, No. 384,170, issued June 5, 1888, copy of which is annexed,

Report that: They have examined the semaphore in use on the road and carefully considered the claims made by the inventor and announced in the paper read by him before the FRANKLIN INSTITUTE, at the meeting, Wednesday, November 21, 1888.

The semaphore proposed by Mr. Gregory, in 1841, has been so universally introduced on the leading railroad lines as to require little comment. Professor Koyl's invention

makes the semaphore not only as useful at night as during the day, but it also adds to its utility during the daylight, when the arm can be seen, by reason of its exceeding whiteness from the reflection of the sky, after it has been dropped to the position indicating safety.

Professor Koyl's semaphore arm is made in a curve approximating a parabola, partly covered with glass slightly corrugated to scatter the light.

The parabolic surface is illuminated at night by a lamp placed in the focus of the paraboloid, and the lamp being protected on the plane of the horizontal arm of the semaphore by red glass, shows a strong red band upon the line of the track and for a considerable distance each side of the track, so as to be seen by the men on the engine when approaching the signal on a curve of the road.

The lower part of the lantern used to illuminate being made of clear glass, the arm when dropped to (say) 45°, passes out of the red rays of the light and is made to reflect the light of the lamp and so to present a strong contrast to the red signal of danger visible when the arm is in a horizontal position.

The arm itself being from seven to eleven inches wide, is painted bright red over its surface, with the exception of the medial band of corrugated silver glass, which is four inches wide. The mass of the signal board being red, can be seen during the day in a horizontal position as well as the present semaphore arm, made straight without any reflecting surface. When the arm has fallen to the safety position, the glare from the strip of glass lighted by the sky only, makes the signal more striking during the day than the arm in common use, while at night it presents the great advantage of giving the same red band when the arm is up, and white when it is down, as is visible by day.

(1) Any improvement in the semaphore that will permit it to be seen more clearly during the day is worthy of attention.

The parabolic semaphore can be seen when dropped to an angle of (say) 45°, as a white band of light, more clearly than the fallen arm of the ordinary kind. This is a marked

advantage, as the safety sign is one so strongly emphasized and readily seen.

(2) The semaphore being the standard day signal, it is very desirable that the night signal shall be the same as that used by day.

The parabolic semaphore accomplishes this object.

(3) In making any change in the signals of a railroad, that invention commends itself that can be used without any great change in devices already in use and considered standard.

The parabolic semaphore can be placed on the same irons now used to carry the ordinary semaphore, which is valuable only during daylight; and there is nothing new to be learned by the trainmen.

(4) This signal admits of the adoption of other colors than red and white, for since the reflecting surface gives to the eye whatever colors the lantern used is arranged to furnish, several colors can be expressed by one lantern at different angles of dip.

(5) The band of corrugated glass reflecting the red light of the lantern at night being but four inches wide and being imbedded in the wider surface of the semaphore arm is well protected and less liable to be damaged than is the case with numerous small mirrors at many angles on the ordinary plane arm (which had been tried) and is much more perfect in its action.

Your committee have considered the action of the instrument, both in regard to the extreme distance at which it can be seen and also in regard to the nearness of approach of the observer to the post supporting the arm, and they find it fully meets the requirement, as the distinct color of the mirror ceases to be visible to the engineer only within about fifty feet of the post in passing it and is clearly visible from a much greater distance than the ordinary plane arm. After the red band of reflected light has ceased to be clearly visible, by reasons of the nearness of the observers, the arm is then visible as an object lighted by the lantern. This obtains in a marked degree when in a horizontal position.

They feel that it fully meets the claims made for it by

the inventor as expressed in the paper read before the INSTITUTE, a copy of which is herewith submitted. In consideration of the value of the invention, intended to add to the safety of the travelling public, your committee recommend the award of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to Prof. C. Herschel Koyl for his parabolic semaphore.

[Signed] COLEMAN SELLERS,
Chairman Sub-Committee.
G. MORGAN ELDRIDGE,
BERNARD RAMKE,
LINO F. RONDINELLA.

Adopted, April 3, 1889.

[Signed] S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

(The following additional facts have been furnished by Professor KOYL.)

The experience of the past nine months has done much to demonstrate the value of the parabolic semaphore in practice and to eliminate the defects of its early construction.

In developing the glass of the reflector, the approximate formula for divergence originally given was found not sufficient for practical purposes, and the glass is now made in accordance with the following formula, which is mathematically accurate. To diverge the light 16° from the direction of the axis requires the surface of the glass to make an angle of 8° with the parabola, and this is attained at blending intervals, for both directions from the axis, and for any intermediate degree of divergence by a wave surface in which, if the wave length be three-eighths inch, the amplitude must be—

$$\tfrac{3}{8}\text{ inch} \cdot \frac{\textit{vers.}}{4\,\textit{sin.}}\, 8^\circ = \text{approximately } \cdot 006 \text{ inch};$$

and vertical divergence is gained by a wave surface at right angles to this, so that when one is superposed upon the other, divergence in all directions is the result. The appear-

ance of the glass is shown in *Fig. 1*, and the accuracy of the formula will appear from the following demonstration in

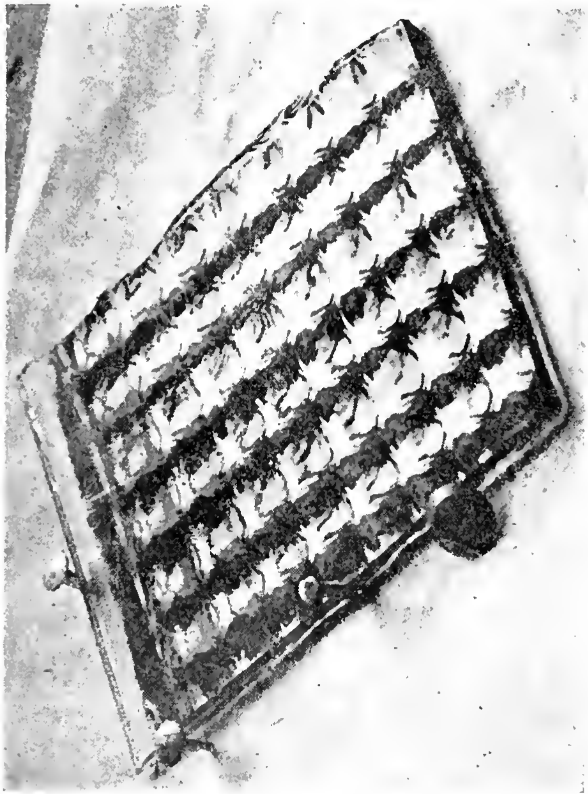


FIG. 1.

which the wave surface is represented (see *Fig. 2*), with the circles from segments of which it is made and in which—

bg = wave length;

bc = $\frac{1}{4}$ wave length;

ab = amplitude;

the angle $dcb = 8°$;

and the triangles dcb and cob are similar, so that—

$ab = 1 - cos. 8°$ (or $vers. 8°$);

$$ab : bc = vers.\ 8^\circ : sin.\ 8^\circ, \text{ and}$$

$$ab = bc \left(\frac{vers.\ 8^\circ}{sin.\ 8^\circ} \right)$$

$$= \frac{bg}{4} \times \frac{vers.}{sin.} 8^\circ$$

$$= {\cdot}006 + \text{inch.}$$

It was further found desirable to have the illumination of the signal uniform from its outer limit of visibility to

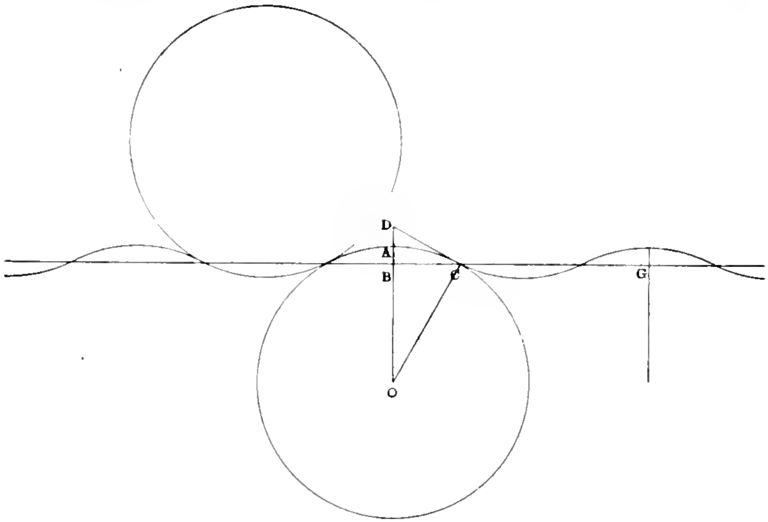


FIG. 2.

the foot of the pole, and for this purpose the upper edge of the glass has been curved, as shown in *Fig. 3*, and the band of light is now visible on the track in immediate proximity to the foot of the pole.

There has never been any question of the value of the signal at night, since, if enginemen are instructed to run by the *position* of the blade, color being used to distinguish "home" from "distant" signals, the trains are relieved from accidents which might follow the breaking of a red or a green glass in the ordinary signal, or the engineman's mistaking a light; but the appearance of the parabolic semaphore by day is not only striking but most important.

It has long been an eyesore to theorists and sticklers for consistency that, though red is used as the danger signal at night, a train must in the daytime regard that same red as a safety signal if only the board is at 45° instead of being horizontal; or, in other words, they argue that as long as color signals are in use, the safety signal by day should be not only at 45°, but *white;* and for the first time in the history of signalling, a semaphore which is red when horizontal is brilliantly white when dropped, the effect being due, of course, to the reflection of the sky light which passes through the vicinity of the focus to the blade, and

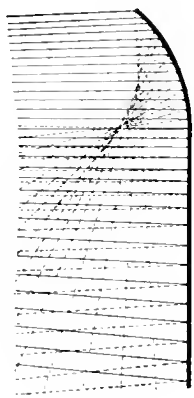


FIG. 3.

further adding to the utility of the signal in that it becomes very conspicuous, and the necessity for a sky background is obviated.

The full-page illustrations show as nearly as may be the appearance of the signal in its "danger" and "safety" positions, by day and by night, and it is seen that, in both cases, for "danger" the signal is horizontal and red, and for "safety" 45° and white. (See *Frontispiece.*)

Fig. 4 shows the semaphore in elevation and plan.

Distant signals are, of course, similarly, green and white, and no movements ever take place in the lamp or in the colored glasses which are part of it.

The parabolic semaphore being both distinct and distinctive, finds its greatest usefulness in the vicinity of cities where lights are numerous, in wooded or hilly country, where the background is dark, and near curves, where it is necessary that the signal should quickly catch the attention of engine or trainmen.

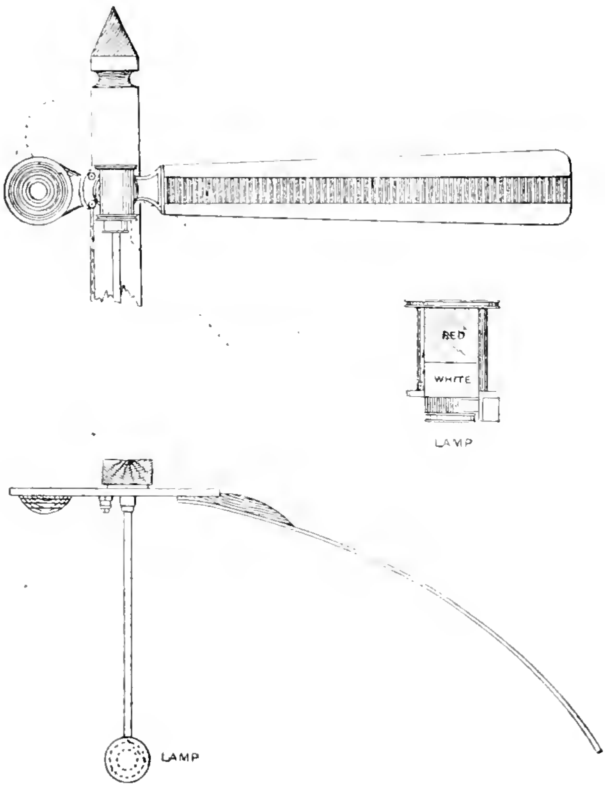


FIG. 4.

The present condition of the glass, which has been in service during the winter, relieves all anxiety on the score of permanency, and snow-storms have not been found seriously to detract from the utility of the signal, because dry snow never lodges on the blade, and wet and frozen snow are themselves excellent reflectors.

OTIS C. WHITE'S ADJUSTABLE EXTENSION MOVEMENT IN BALL-AND-SOCKET JOINTS.

[*Report of the Committee on Science and the Arts.*]

[No. 1416.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 4, 1889.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

OTIS C. WHITE'S ADJUSTABLE EXTENSION MOVEMENT IN BALL-AND-SOCKET JOINTS,

Report that: This invention consists of a ball-and-socket joint, with the novel and original feature of permitting a longitudinal adjustment of a rod through the axis of the ball, in addition to the ordinary swivelling and rotating movements, and of firmly clamping the rod in any desired position.

The construction by which this is accomplished will be understood by referring to the accompanying tracing (*Fig. 1*).

The ball *B* is made in three separate segments, with sufficient space between them to allow for contraction. The clamping sockets *C C* have each a narrow annular bearing fitting the surface of the ball sufficiently near the equator to produce a powerful wedging action. A conical opening in each socket permits an oscillation of 60° or more. The sockets are held together by two bolts, *D* and *F*, having adjusting nuts, *I* and *J*, on their lower ends, in addition to which the bolt *D* has on its upper end a nut with operating handle *E*. This arrangement permits a delicate adjustment of the amount of compression, which the motion of the lever, by forcing the clamps together, will produce upon the central rod.

In addition to its mechanical functions, this joint possesses the merit of not being dependent upon accurate

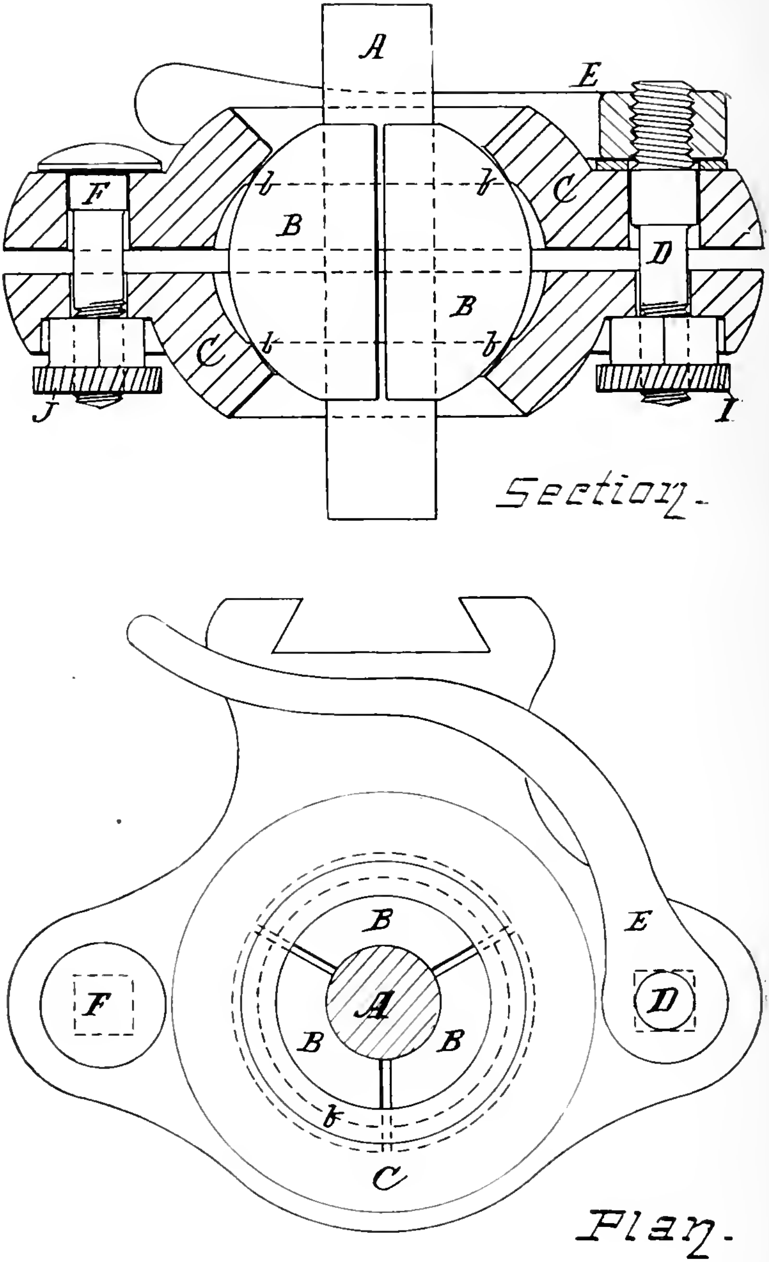


FIG. 1.

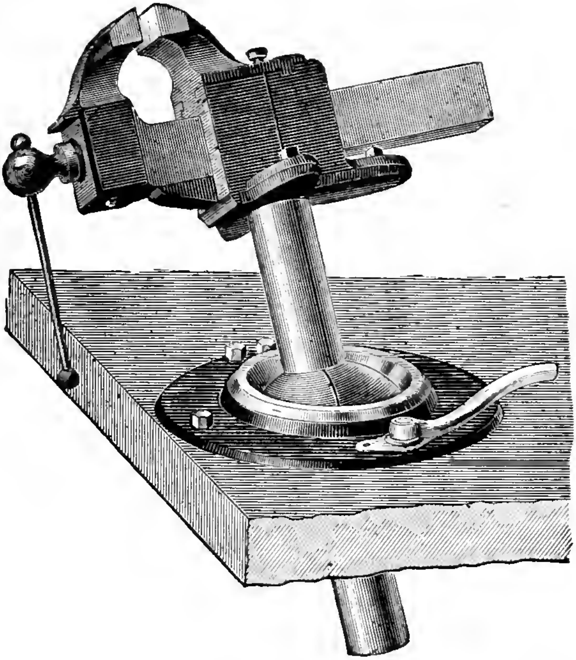


FIG. 2.

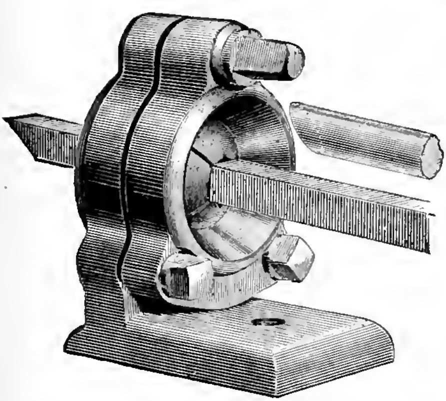


FIG. 3.

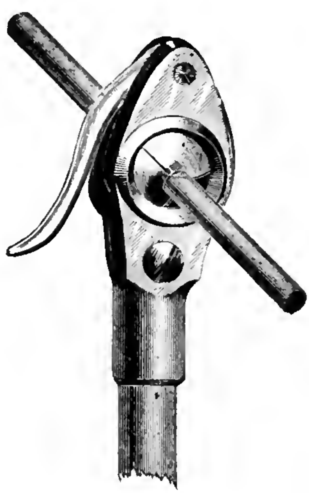


FIG. 4.

fitting for its adjustability or holding power, because each part automatically finds its bearings and receives its share of the stresses. For nearly all commercial purposes, the joint can be made without any tool finish. The ball segments are cast separate and hollow, bearing on the central rod only at their ends, and are held apart by a flat steel

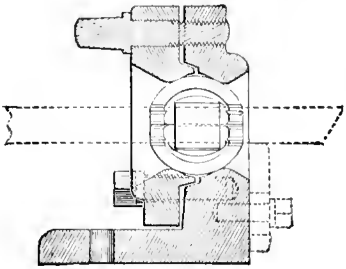


Fig. 5.

spring bent in the form of a cylinder and placed in this hollow space. The annular bearings of the clamps can be cast on chills and the bolt-holes can be cored, so that the joint, while being superior in the convenience and rapidity of its adjustments and the firmness of its grip, and supplying a new and additional movement to the ball joint,

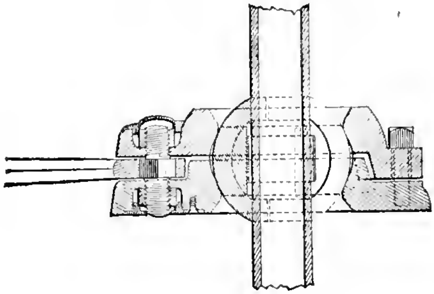


Fig. 6.

can at the same time be more cheaply manufactured than any other device known to your committee which will accomplish the same purposes.

The invention is capable of numerous useful applications, many of which were examined. Its originality is

attested by the broad claims allowed in Patent No. 259,957. granted to Otis C. White, June 20, 1882.

We recommend award of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to OTIS C. WHITE for his adjustable extension movement in ball-and-socket joints.

[Signed] WM. H. THORNE,
Chairman Sub-Committee.
THOS. P. CONARD,
D. E. CROSBY,
W. M. MCALLISTER,
LOUIS H. SPELLIER,
C. CHABOT.

Adopted, April 3, 1889.

[Signed] S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

THE EXPERIMENTAL DETERMINATION OF THE LAW OF VARIATION OF THE ELECTRO-MOTIVE FORCE IN THE ARMATURE OF A WESTINGHOUSE DYNAMO.*

BY LEWIS SEARING AND SAMUEL V. HOFFMAN.

In the mathematical discussion of alternating currents, it has been customary to assume the law of variation of E. M. F. as that of a sinusoid. Previous experiments to determine this law have been made upon machines containing *no* iron in the armature. Recently, Dr. Louis Duncan, of the Johns Hopkins University, has conducted experiments in which he found that this assumption was approximately true with the Siemens machine.

We propose to investigate this law upon a machine *con-*

* Graduation Thesis at Stevens Institute of Technology, Hoboken, N. J., 1888.

taining iron in the armature. To observe the effect produced by varying the conditions, we imposed the following:

(1) Field current, . .	2·15 ampères;	load, = 0;	speed, = 1,000
(2) " " . .	4·3 "	" = 0;	" = 1,000
(3) " " . .	4·3 "	" = 14;	" = 1,000

The machine used was the No. 1 Westinghouse Dynamo in the electrical laboratory of the Stevens Institute; rated at sixty-five horse-power, and requiring a current of seven ampères in the field, when run at its full capacity. The power conveniently available being only a thirty-five horse-power Buckeye engine, accounts for the small figures taken for the conditions.

METHOD.

The method used was suggested by Dr. W. E. Geyer, of the Institute, who had employed it, as early as 1881, on a continuous-current machine. It consists in measuring the difference of potential existing between the brushes for an instant of time, at any angular position of rotation of the armature, by charging a condenser and discharging it through a high resistance galvanometer.

In the practice of this method it was necessary to devise some means of closing, for an instant, the shunt circuit across the brushes to the galvanometer, while the armature was in the desired position of rotation. To effect this, the following apparatus was devised: A ring of brass *R* (*Fig. 1*) was sprung around the turned portion of the bearing nearest the pulley, and to this was secured the piece *A*, to which, at *B*, was hinged the piece *C*, held against *A* by a spring and adjustable outward by the screw *D*. At the upper end of *C* was secured a block of hard rubber *E*, and to this was fastened the plate carrying the steel-wire spring *F*, by which contact was made with the steel piece *G*, highly tempered and ground to an edge in the direction of its length. The steel piece *G* was fastened to the end of the armature furthest from the commutator, with its ground edge parallel to the shaft by means of a V-shaped brass, *H*, and at such a distance from the shaft as to just pass, in its motion with the armature, the contact spring *F*. In holding *H* to the arma-

ture, hard rubber was used as an insulator and electrical connection made between it and one of the commutator rings by a rubber-covered wire running through the air space in the armature. Fastened to the bearing of the

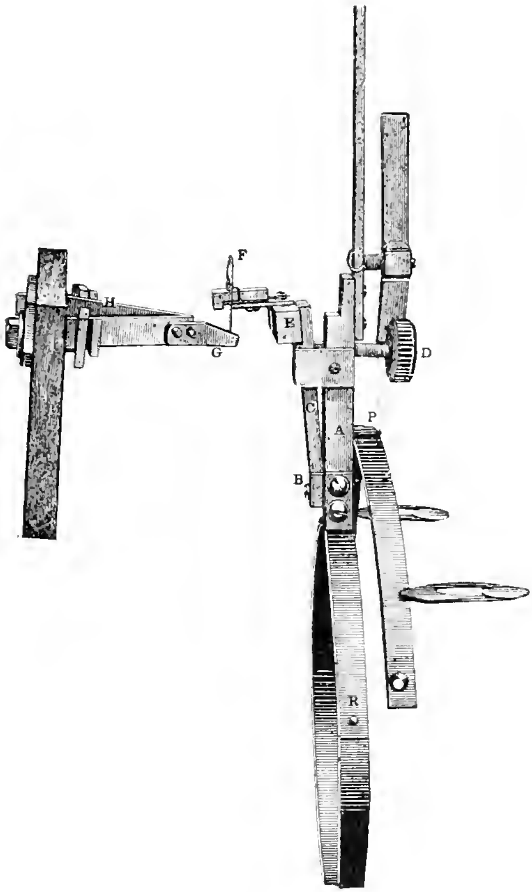


FIG. 1.

machine was a graduated arc of 120°, concentric with the brass ring. A pointer *P*, on *A*, served to determine the angular position, in degrees, of the armature at the moment of contact, at which time the E. M. F. existing in the armature was measured.

The contact spring F, as finally adopted, consisted of a steel wire 0·034 inches in diameter, bent as shown in *Fig. 6.* One end was inserted in the hole K, and secured there by a set screw, and the free end passed through a hole, slightly larger than the wire, at J, sufficiently far to make contact with the rotating piece G.

Fig. 2. is a diagram of the connections. A represents the wire of the armature; B, B_2 the brushes; M the main circuit; C_1 the steel contact-piece revolving with the armature and connected with B_1. C_1 makes connection with the condenser, C, once per revolution by coming in contact with the steel spring C_2 connected with the condenser by the line wire. B_2 is placed in connection with the condenser by the wire and the discharging key, as shown.

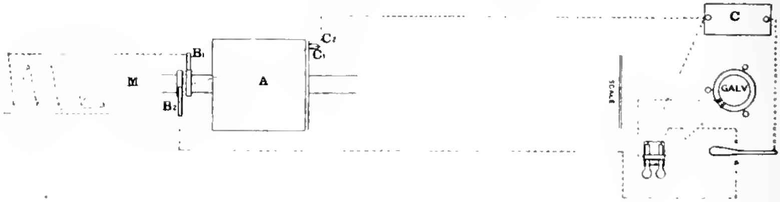


FIG. 2.

The necessity of placing the measuring instruments a considerable distance from the dynamo introduced a difficulty in the shape of self-induction, due to a long line. This we overcame as much as possible by using bare copper wire 0·008 inch in diameter. This line was supported on glass rods, fastened to wooden supports, except for a distance of seven feet where they were fastened to a pine board for protection, and for about four feet where they passed through glass tubing. The wires ran parallel 4·5 inches apart their whole length, a distance of 150 feet.

The measuring apparatus used was a "high resistance Thompson reflecting galvanometer," with its accompaning shunts $\frac{1}{9}$, $\frac{1}{99}$, $\frac{1}{999}$, and two mica condensers of one micro-farad capacity (variable, etc.), all of Elliott Bros., London, The scale used with this galvanometer was placed thirty-three inches from the needle and had divisions measuring forty to the inch.

The first difficulty experienced in measuring was that arising from the large static charge induced in the line wires and the metal of the machine by the action of the belts. The first step towards removing this was to connect the body of the machine with the ground, and to furnish pointed wire collectors to the belts, also connected with the ground. Although this removed much of the charge, there still remained enough to charge the 0·1 motive force condenser, and give with the one-ninth shunt a mean but not very constant deflection of twenty-one divisions. As one volt gave a deflection of about three divisions with the one-ninth shunt, this would have seriously interfered with our measurements. At first, it was a question whether we were measuring the potential of the condenser due to the static charge, or that due to the dynamo. The following considerations, however, show that we were really measuring the E. M. F. of the dynamo; for, suppose the condenser had become charged from the belts, etc., to a potential *greater* than that which the armature would furnish, then, as soon as the contact piece completed the circuit which includes the condenser and armature, the condenser would, by reason of its greater potential, immediately discharge itself through the armature until its potential equalled that of the armature, which is the E. M. F. we would measure. If, however, the condenser was charged to a potential *less* than that of the armature, then upon completion of the circuit, the armature, from its being able to supply an infinitely larger current than the belts, etc., would charge the condenser instantly to its own E. M. F., which is what we measure, as before. Moreover, our experiments showed that, in this particular case, the current from the belts required quite a perceptible time to charge this condenser, and give even a measurable charge. An additional fact that no error was introduced by this static charge is evident from the regularity of the readings and the smoothness of the curves.

Two revolution counters were used during the test; the first was an ordinary one, which was held in place by hand while taking speed. This was superseded by a second, the

pinion of which engaged with a worm inserted in the end of the dynamo shaft. This counter was arranged to be thrown in and out at will, and the number of revolutions automatically recorded.

The order of procedure in applying this method was as follows: The dynamo and instruments for measuring potential being about 150 feet apart, in separate rooms, the observers in each room were connected by telephone and bell. The dynamos being started and everything made ready, signals were exchanged to that effect. Then the observer in the dynamo room adjusted the contact apparatus for the first position, numbered 12°, observed the indication of the ammeter in the field circuit, which, if not as desired, was made so by adjusting the resistance in that circuit, rang "go ahead" signal to the observer in the measuring room and upon receiving his answer, threw in the speed counter and noted the time. The observer in the measuring room, immediately upon answering the "go ahead" signal, commenced a series of measurements of E. M. F. of the condenser, by noting the swing of the galvanometer needle, as follows: The charging key was placed in "charge" position and left there a few seconds. One reversing key was then closed and almost simultaneously the condenser was discharged through the galvanometer. As soon as the galvanometer needle came to rest, another charge was measured. These measurements occupied from three to four minutes. Upon the completion of each series of measurements, "go ahead" was signaled to the dynamo room for the contact to be changed to the next position, and the above operations repeated. Speed was usually counted for three minutes, or nearly the whole time of measuring, and therefore the average speed for each series was obtained quite accurately. The variation in the field current during a series was never over 0·2 of a division = 0·04 ampère, hence no correction has been introduced for this. The speed in some cases changed quite perceptibly. To be able to make a correction for this, we determined the law of variation of E. M. F. with the speed in this machine. To do this, we made simultaneous measurements of speed and E. M. F., the latter at posi-

tion of contact apparatus which gave the highest readings, *i. e.*, 34°, a point in the upper part of the curve. This law, as represented by a curve, showed a direct variation, it being almost a straight line. Upon this the corrections for speed were made, the value of the E. M. F. being computed for 1,000 revolutions per minute.

At the beginning and end of each run, which occupied about four hours, any variation of H was observed by noticing the swing of the needle produced by the condenser when charged from a cell of Leclanché battery, kept especially for that purpose. The variations were so slight that they have not been introduced in our corrections.

The corrections to be applied to the readings of the galvanometer were:

(1) A geometrical one, from the fact that the swing of the spot of light measures the $tan\ 2\ a$, while the charge is proportional to $sin\ \frac{1}{2}\ a$.

(2) A correction due to the induction of the shunts.

(3) A correction for the ratio of the shunts.

(4) The resistance of the air to the swing of the needle.

(5) The correction for speed.

The first, second and fourth corrections were obtained in one experiment, by comparing six gravity E. M. F. cells, which were approximately of the same E. M. F. by the condenser method. Then by using one of the shunts employed in the regular work, we noted the swing produced by 1, 2, 3, and so forth cells coupled in series. Knowing the exact comparative values of E. M. F. which the coupled cells ought to give, and by experiment the swing they did give, and taking the latter for ordinates and the former for abscissæ, we obtained a curve for converting the one into the other. This curve approached very closely to a straight line, the ordinates (or galvanometer readings) of which are about four per cent. greater than the abscissæ (or E. M. F. values). This correction was made graphically.

The shunt ratio and induction correction were obtained in one experiment, and amounted to 0·76 of one per cent., which was neglected.

The correction for speed was also made by the graphical method, and afterwards tested by logarithms.

The instrument used for measuring the field current was a portable Thompson galvanometer, and for measuring the main current of the Westinghouse, the Westinghouse ammeter usually accompanying the machine, which was previously calibrated by a continuous current. This instrument could not be relied upon within 0·25 of a division with the current we used.

The main circuit was through a large German-silver rheostat, strung overhead in the dynamo room. When running at night, some of this current was used for lighting.

SPRINGS.

Upon the apparatus for obtaining almost instantaneous connection between the armature and condenser, or, more

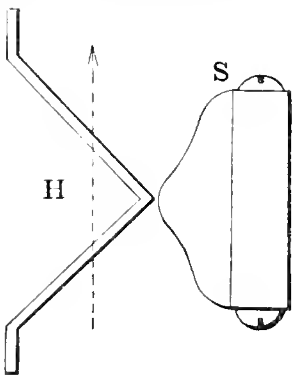


FIG. 3.

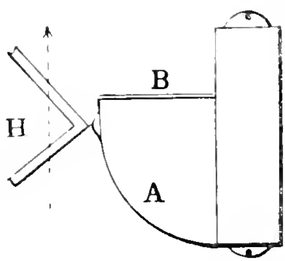


FIG 4.

strictly, upon the pieces which come in such rapid contact, 1,000 per minute, depends the success of this method. Our difficulties and the manner of overcoming them may be of assistance to others. In the first arrangement of these pieces, the end of the brass V, *H* (*Fig.* 3), which was fastened to the revolving armature, came in contact with the spring *F*, made of a strip of spring brass, $\frac{3}{8} \times \frac{1}{64}$-inch, and bent in the form shown in the figure. With this spring the wear was such as to cut through the thin brass in about two hours, and as this wear materially lengthened the arc

of contact, we were compelled to abandon it. We then replaced the brass spring with pieces of clock spring, of several widths and thicknesses, tempered throughout, softened at ends, softened at the middle, and softened throughout; but even the most durable of these did not last over an hour. The majority of them broke at *S*. We then tried the brass spring again, this time capped with steel at its point of contact to prevent wear. This lasted about two hours. We next tried a heavy brass spring ($\frac{1}{2} \times \frac{1}{32}$), tipped with steel, made as shown in *Fig. 4*. The part *A* has a spring outward and is held in check by *B*. The object of restraining the outward tendency of *A* is an important one, and is to shorten its time of vibration to much below 0·001 minute. The next arrangement is shown in *Fig. 5*. The

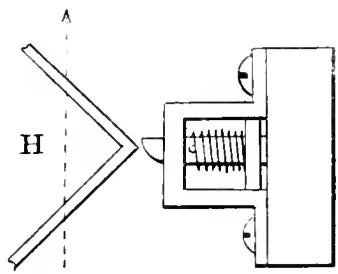


Fig. 5.

piece *H* in passing struck against a steel pin, which action forced it inward against a light spring coiled about it. This arrangement produced such a jarring and such a wear on *H* as to make its use impracticable. From the experience of these springs we learned the causes of failure; one, that the springs used were much too heavy, and another, the most essential, that the path of the contact point of *H* was parallel to the surface of the part with which it came in contact, producing a direct blow and slide; whereas the path of each should have been tangent to each other, in order that the parts would approach and immediately recede, thus allowing, by means of the adjusting screw, a contact of almost any delicacy. The longer the arc of contact, the result of construction or wear of parts, the greater the variation between readings taken at any point in the

curve. To prevent this, we arranged to have a knife-edge of hardened steel strike the end of a very light steel-wire spring (·034 inch diameter), as described in a former part of this paper.

The first spring used was bent as in *Fig. 6*, but without the coil at *G*, and broke at the point where it was clamped by the set-screw, before the end of a run. We then coiled it twice at *G*, care being taken in fastening it to have the coils press firmly against the plate, in order that the bending should be confined to the coils. These springs would last about six or seven hours, and were readily and accurately replaceable; so, to avoid the annoyance of break-

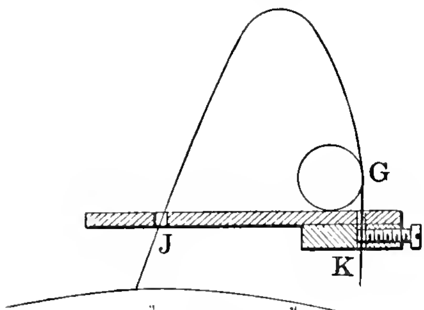


FIG. 6.

age, a new spring was used for each run. We then obtained a clear yet light contact that was in every way desirable.

TABLES.

Tables giving the results of the observations were made, a very short abstract of one being here given to illustrate the form.

The first column on the left gives the position, in degrees, of the arc previously mentioned, at which contact was made. This arc, of which the 0° was arbitrarily assumed, was for the purpose of measuring the abscissæ of the curve, and for determining the position of the armature coils in reference to the field magnets for any E. M. F. in the armature coils. The 0 of the *curve* happened to come between position 14° and 15°, and as the readings about these points were uncertain, we started measuring at a point a trifle before the curve cut the axis.

Column 2 gives the shunts used, and as the condenser was generally the same value throughout a run, its value has been placed at the head of the tables and any change noted in the column of "Remarks."

Column 3 contains the actual readings (right and left) made on the galvanometer scale.

Column 4 is the mean of these readings reduced to a value which would be given by the $\frac{1}{99}$ shunt.

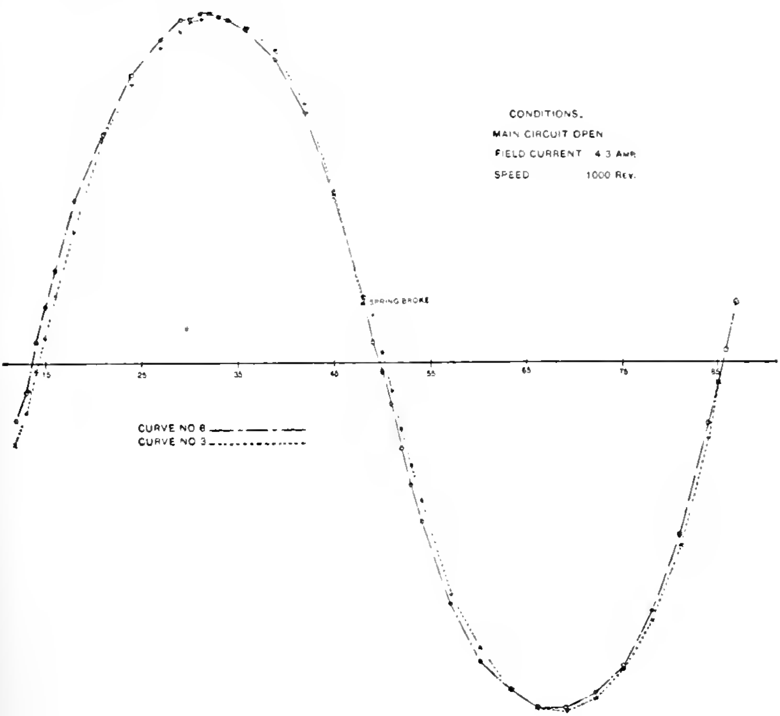


FIG. 7.

Column 5 contains the readings with all corrections applied, but reduced, as in column 4.

The remaining columns explain themselves.

These curves were taken under the same conditions, in pairs, so as to verify each other, as in *Fig.* 7, and then the mean readings of the two plotted, as in *Fig.* 8. In order to show how closely they follow the "sine law," a sinusoid has then been traced over them and is the inner line, *Fig.* 8, and

as will be seen on inspection, the agreement is quite close; the most marked difference occurs between the positions 16° and 27°, 36° and 48°, and on the reverse curve, positions 52°–63°, 72°–84°, where there is a sort of bulging out in the direction of rotation of the armature. The cause of this is not known, so far as we are informed.

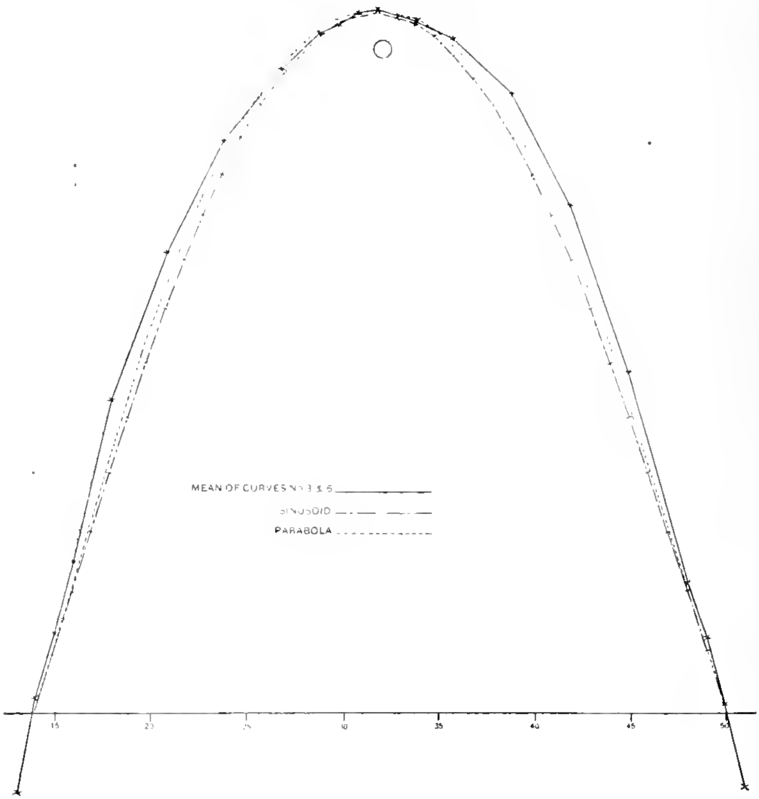


FIG. 8.

The direction of rotation of the armature is shown by the arrows.

Fig. 8 shows only one branch of the curve. Over this curve has also been traced a parabola, the focus being at the point O. While the curve cannot be said to follow the "parabola law," as it has two branches and the parabola only one, still it will be noticed that the parabola is much nearer the true curve, for one branch only, than the sinusoid.

CURVE No. 1

Conditions.—Main circuit consisted of about 36 ohms German-silver wire in parallel with eleven lamps of 16 candle-power in series. Field current, 4·3 ampères.

1. Microfarad Condenser. May 8, 1888.

Pos.	Shunt.	Readings. Left.	Readings. Right.	Mean Reading	Corrected Mean Reading	Speed	Current in Main Circuit	REMARKS.
		—46	43					
12°	1-99	46	43	45·	47·	954	14·0	. . . .
		48	44					
		—285	263					
13°	1-9	283	261	27·2	27	955	14·0	. . . .
		286	262					
		—68	65					
		63	54					
14°	1-9			5·7	5·5	965	14·0	. . . .
		48	52					
		61	45					
		+98	100					
15°	1-9	95	101	10·08	10	956	14·0	. . . .
		109	102					
		-33	30					
16°	1-99	32	31	31·5	33·	950	14·0	. . . .
		32	31					
		64	63					
18°	1-99	68	63	64·3	67	947	13·7	. . . . .
		66	62					
		-114	108					
21°	1-99	115	109	112·	114·	957	13·7	. . . .
		116	109					
		151	138					
24°	1-99	148	140	144·5	149·	951	13·7	. . . . . .
		150	140					
		+173	160					
27°	1-99	173	164	168	172	949	13·7	. . . . . .
		175	163					
		+182	167					
29°	1-99	181	167	174·1	178·	952	14·0	. . . . . .
		181	167					

CURVE NO. 1.

Pos.	Shunt	Readings. Left.	Readings. Right.	Mean Reading.	Corrected Mean Reading	Speed.	Current in Main Circuit.	REMARKS.
54°	1·99	— 75 76 73	70 71 70	72·5	75·	943	13·9	. . . . . .
57°	1·99	— 118 119 119	112 113 111	115·3	119·	946	13·9	. . . . . .
60°	1·99	— 150 150 150	141 141 141	145·5	147·	936	13·7	. . . . . .
63°	1·99	— 174 171 173	161 163 161	167·1	173·	943	13·9	. . . . . .
66°	1·99	— 186 184 184	173 181 181	181·5	187·	942	13·9	. . . . . .
69°	1·99	— 190 189 190	175 175 175	182·3	188·	938	13·9	. . . . . .
72°	1·99	— 184 186 187	172 173 173	179·2	185·	943	13·9	. . . . . .
75°	1·99	— 172 172 172	160 160 161	166·1	171·	943	13·9	. . . . . .
78°	1·99	— 147 145 144	130 136 135	140·5	145·	949	14·0	. . . . . .
81°	1·99	— 98 103 99	97 95 94	97·7	101·	950	14·0	. . . . . .
. . . . . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .	. . . .
84°	1·99	— 42 44 45	44 43 45	43·8	46·	943	14·0	. . . . . .
85°	1·9	— 193 193 186	182 180 184	18·63	19·	943	14·0	. . . . . .
86°	1·9 0	+ 7·0 − 9·8	. . . . . .	·84	·85	958	14·1	E. M. F. readings very variable.
87°	1·9	+ 235 238 210	214 203 190	21·5	22·	943	14·0	. . . . . .

HEATING AND VENTILATION OF PUBLIC BUILDINGS.

By Thomas Elkinton.

In the sixth month number of *The Student*, for 1888, was published an article furnished by me at the request of the editor on the subject of "Ventilation," which treated of a few general principles, and of their applicability to dwellings and other buildings, but the scope of the article did not cover more than the commencement of the subject and did not touch upon any of the methods of accomplishing the desired results.

It is a hopeful sign that the public mind is becoming more and more awake to our needs for improved ventilation in large buildings and to realize that while good progress has been made in civil and mechanical engineering, and much attention paid to architecture and substantial building, sanitary engineering and hygiene have been greatly neglected.

Probably one reason for so little progress having been made in these matters is that in the first place the problems are really very difficult ones to deal with, and the ability to deal with them, though obtained partially by study, comes better by more extended and continued observation than is usually given to it, and very unfortunately, ventilation is a subject on which one is tempted to enjoy a confidence inversely as the extent of his knowledge.

With every one thus the director of his own ventilation and his own plans of hygiene, the demand for persons skilled in the profession in these lines has heretofore been very limited, and buildings for generations have been erected with but little provision for a proper air supply for the inmates; and, as a result, the hygienic condition of most of our buildings is far from creditable to an age pretending to civilization and refinement.

Professor Morse, in his *Japanese Homes and their Surroundings*, remarks that a Japanese "would look upon the usual

public gatherings of our people in lecture-halls, school-rooms and other closed apartments * * * as filthy in the extreme." A judgment which the sooner we realize as correct, and the sooner we aim to render untrue, the better for our general health.

As a rule, the offices in which business men spend most of their time become very foul when the weather requires the windows closed; lecture-rooms generally dismiss their audiences in profuse perspiration, and with lungs which have been bathed with the exhalations of many others; and court-rooms and other places of mixed assemblages hold their occupants and attenders for hours in an atmosphere totally unfit for the health of human beings.

These evils being apparent to the most careless observer, and the necessity for improvement partially acknowledged, the next step is the arousing of public interest to the point of declining to rest short of their removal, and to publish methods by which this may be effected.

As above intimated, the first idea to dismiss, is that properly heating and ventilating a large building, as it should be done, is an easy thing to accomplish, and that while we must not stop short of good results, far in advance of what we have as an average been heretofore contented with, we must realize that perfection is a matter of the future, or at least not of the immediate present.

He who deals with currents of air finds, in its elasticity, laws of motion, temperature and moisture, features which baffle him at unexpected turns, however long his experience and close his observation.

Experience, however, does teach, and knowledge is power, even when dealing with air, and although we may be but upon the threshold of what we may in the future accomplish in heating and ventilating our buildings, we have already enough at command, if we will but use it, to vastly increase our physical comfort and welfare, and may leave to our successors to improve as they can upon our methods and appliances.

Another matter to be dismissed from the public mind is the idea that heating and ventilation are to be satisfactorily

obtained without paying a reasonable price for both plant and maintenance.

Too often is it the case that the expenditure of a few thousand dollars for matters of architectural effect or decoration of interiors is borne with greater equanimity than the expenditure of an equal amount for the more useful appliances of a good and healthful air supply for the inmates.

It is not well to build and finish offensive to the eye, but much better to fail to please the eye than to fail of an adequate food for the lungs, and to entail consequent impoverishment of the blood.

To heat without ventilation may be done at comparatively little cost, but as the ventilation for large and continuous occupancy means the changing of the volume of air at short intervals, the cost will be greater, though not in proportion to the number of changes and not in proportion to the increased benefit.

Fifty years ago, buildings were heated by stoves and had no provision for change of air beyond the leakage of the doors and windows and the flow of air through the walls. It may be remarked in passing, that a room heated by stoves will remain for a short time surprisingly pure in its condition, because of the rapid transfer of the lower strata to the upper by the currents induced by the hot surfaces of the stoves, but when the volume of the room becomes uniformly bad, as it quickly does, the condition cannot be described in terms of refinement.

No public buildings now are constructed without some recognition of the importance of ventilation, but, as a rule, the recognition is scarcely more than in appearance, providing, as they do, only partial outlets for foul air with scarcely any opportunity for the inflow of pure air, the fact being seemingly constantly overlooked, that while the provisions for the passage of foul air are well enough in themselves, they are of little account without provision for the inflow of pure air.

It is true, windows and doors afford inlets for air, but as the choice between pneumonias and neuralgias and the evils of foul air are not worth discussing, all such sources

of air supply is to be dismissed from a discussion of apparatus adapted to American winters.

Much difference of sentiment exists as to the proper temperature for rooms best promotive of the comfort and health of the occupants, and the ideas of different nations present curious phases.

Curtis tells us that the Chilians, with a climate similar to that of Washington, think that fires in a house are unhealthful, and wear their heavy wraps indoors as well as out, and although coal is cheap and wood abundant, sit in their houses with noses blue and teeth chattering, and at fashionable gatherings women appear in evening dress, with the thermometer between 40° and 50°. He also states that the mortality from lung and throat complaints is reported to be immense.

The Englishman, too, sits in his large parlor with a small grate, and considers himself comfortable with the thermometer in the fifties.

The proper temperature for every individual is probably that at which he is most comfortable, and this will vary with the physical condition and manner of dressing; one who dresses very warmly needs but little for wraps, and will be oppressed with a temperature agreeable to one who makes more difference between indoor and outdoor wear.

As "comfortable" points, however, are not in use on the thermometer scales, we must express ourselves by the degrees marked upon them, and in practice an average amount of comfort may be secured in our latitude by about 65° for audience chambers, where the occupants sit with their wraps, 69° to 70° for schools, and 1° or 2° higher for parlors, with elderly people in the family.

Heating a building is generally attended to so far as providing against its being too cold, but the regulation of the temperature to provide against overheating and for the supply of a proper volume of pure air, are points which are very seldom secured.

Omitting for the moment the regulation of the temperature and considering the volume, and without citing all the authorities as to what constitutes a proper air supply *per*

capita, it may be briefly stated that they vary from ten cubic feet to sixty feet per minute, the lower estimate, however, being based upon the theory of each one in an audience receiving at each inhalation a supply of pure air, and discharging it where it cannot be again used, a condition only possible out of doors in a stiff breeze.

Sixty cubic feet of air *per capita*, per minute, for an audience, school-room, or class-room, with much more for the sick-room and the hospital, will, it is to be hoped, at an early day be acknowledged as the requirement for good ventilation, but in the present stage of education in these matters it is probably, as a matter of expediency, better not to state the scientific requirement, but, in order not to defeat the rising tide of healthful sentiment, name forty cubic feet per minute *per capita* as a satisfying quantity for the time.

Forty cubic feet *per capita* per minute means for a class-room with thirty, 1,200 feet per minute; for a parlor of fifty visitors, 2,000; for a school-room of 100, 4,000; for a lecture or court-room of 500, 20,000; and for an audience of 1,000, 40,000 cubic feet; and lastly, for the larger audience of 2,500, 100,000 cubic feet of air per minute, as the requisite air supplies for a moderate estimate of the human needs when thus assembled.

How many of the buildings of the day are thus furnished with an air supply like this, or anywhere approximating it.

Doubtless, these figures are startling to such as have not considered them, but they are not unreasonable, even if we have lived for many years with but one-fourth or less of the supply, when we have been at lectures and elsewhere in large audiences and crowded rooms.

Suppose each of our heads were encased for a minute in an air-tight box less than three and one-half feet dimension for each side, or forty cubic feet capacity, and had taken about a dozen full inspirations and expirations of our lungs, would we not deem it proper to have a fresh box at the expiration of that minute, especially if, instead of having the air-tight box exclusively for our own use, we were sharing our exhalations with a neighbor, and in turn were partaking of the exhalations of his lungs?

An audience room for 1,000 seats on floor and galleries would be about sixty feet wide, eighty feet long and twenty-five high, and contain 120,000 cubic feet, and the introduction of 40,000 cubic feet per minute would change the entire volume once in three minutes, or twenty times per hour, a change which it is to be hoped the future will deem little enough, but is immensely in advance of the average present usage, which probably often does not change more than three or four times per hour, if even that frequently. For reasons which I cannot explain, unless it be that for the same percentage of vitiation, the unpleasant odor developed is less when the air is quickly changed than when it is slowly changed, I am inclined to the view that there will, for large, crowded rooms, be the same apparent sweetness, on a less inflow *per capita*, than in a smaller room with fewer in it. Thus in a class-room of thirty, with at least twenty feet *per capita* of inflow, the room has seemed more foul to me than a lecture-room crowded by an audience of 500 persons did with the same supply *per capita*, or 10,000 cubic feet per minute, and I am satisfied that a sitting-room with three or four occupants and closed doors will not remain pleasant short of sixty cubic feet per minute air supply, and that a class-room requires forty feet *per capita*, and that a larger audience will be equally comfortable with a little less; but without explaining these differences, I would have the air supply whenever possible up to these requirements.

The degree of temperature and the volume of air per minute to be maintained having been fixed upon for our needs, further details remain to be considered.

There are probably but a few buildings in existence in this country in which, on continued occupancy by large assemblies, the temperature does not, in a short space of time, rise to an uncomfortable degree, even, it may be, so much as 20° in the course of an evening or single session, and be maintained at these points, although the closing of registers and radiator valves has discontinued the source of applied heat. Apart from the heat of the lamps and gas lights, the main source of increased heat comes from the

audience, each one of whom is a human stove of 98° temperature, radiating what with a few in a room is scarcely perceptible, but with many produces a great increase, and hence it is that while for the warming of a room in cold weather previous to its occupancy the incoming air must be at a comparatively high temperature, it must be greatly reduced after the human stoves have occupied the room and their wraps and outside clothing, cooled by the weather before reaching the room, have become of the same temperature as the room.

As we are considering only the problems of cold weather, we dismiss as dangerous and barbarous the relief of overheated rooms by the opening of doors and windows to the outside air, and can allow of no arrangement but that which supplies the place of the outgoing impure air with that which is fresh and has been properly warmed.

Considering next the principles to govern the arrangements for the exit of foul air from occupied apartments, there has been more or less controversy as to whether ventilation should be from top or bottom, with the probably now well-accepted result that both are correct, according to circumstances.

In a room with few occupants, the greater part of the air exhaled from the lungs cools and falls to the floor, being also increased in specific gravity by the impurities added to it in the process of breathing, and hence for sitting rooms and chambers, the floor line (not the line above the washboard, as mechanics often insist and too many architects allow) is the proper level for the foul air outlets.

Doubts have been expressed by well-informed men as to the necessity and importance of floor ventilation; but besides the obvious advantage of drawing off the layer of cool air apt to rest upon the floor level, the experiments of the late John M. Whitall, some years ago in the sick wards of the Philadelphia Hospital, by which he found that as he lowered the outlet for foul air by successive steps until he placed them at the floor line, he lowered the sick rate of the ward, demonstrates too conclusively to admit of cavilling

the importance of floor-line ventilation for rooms of small occupancy.

It is true, a portion of the lung exhalations are volatile, and to be found at the top of the room, and for these and the heated gases from lamps and gas-lights a small outlet at the ceiling would be correct; but as open registers at the ceiling would on ordinary occasions be but an outlet for pure air, and a waste of fuel in consequence, it is safe to dispense with them in ordinary sitting-rooms and chambers and trust to the dilution of the upper strata by the warm air rising from the registers to the ceiling and thence falling to the floor and passing out at the floor-line vents.

For parlors, however, where large companies are to be occasionally entertained, it is better to provide ample ceiling ventilation for reasons presently stated, but to be careful to keep them closed ordinarily.

The volatile exhalations which are found at the top of the room become more worthy of attention as the occupancy increases in numbers, and they become perceptible "odor" to visitors from the fresh air, and the question arises, Which is the lesser evil, to provide for their removal at the risk of wasting pure air and fuel and destroying the floor ventilation, or to endure the slight odor, which, if the air supply is at all reasonable, is not serious in itself?

With the usual risks of unskilful handling of registers by careless or indifferent attendants, it is probably better to dispense with the ceiling ventilation, but with skilful and interested caretakers, it would probably be as well in class-rooms and similar rooms to have ceiling registers, with rigid rules for closing them when the rooms are not occupied, taking care also that the ceiling outlets shall at best not exceed in area one-fourth of that at the floor line.

In large and crowded rooms, like lecture and court-rooms and meeting-rooms, the problem again changes. In these cases the air supply will or should be much below that of the temperature of the human stoves, and from these human stoves are continually ascending currents of heated air, carrying with them the exhalations of the lungs, and for such rooms, when sufficient inflow of air is supplied, the

ventilation may safely be at the ceiling; providing, however, a trifling outlet at the floor for circulation purposes when warming the room previous to occupancy, at which time the ceiling outlets should be closed.

Allusion may here be made in passing, to what has doubtless surprised many who have attempted to relieve rooms which were originally constructed devoid of ventilation facilities, by adding ventilation at the top or by the pulling down of windows. They have reasoned that if a room was overheated, the hot air at the top would escape if opportunity was offered, and they reasoned correctly to that extent, but they overlooked the fact that for all the air that escaped there must be an equal volume to take its place; and hence in the room described, the supply would come in just where it went out, or rather a stream of hot air would go out one portion of the opening and a stream of cold air pass in the other part. As air does not heat quickly from itself, a chilling body of cold air, whether from ventilator or window top, falls upon an audience, and as they are previously overheated, the sudden blast is a source of danger to them, and the last state of the audience is worse than before.

An old-fashioned meeting-house in Philadelphia, constructed in the beginning of the century, without ventilator appliances, was altered some thirty or more years ago by the addition of central ventilators in the ceiling, opening with cupola and slat-work through the roof, but they were unavailable in cold weather for reasons above mentioned.

A year or more ago, I tried the experiment of covering one of the ceiling openings with a sheet of metal perforated with small holes not exceeding one-fourth of an inch in diameter, knowing that although the cold air must come through some of the apertures as the heated air passed through other apertures, yet I had a hope that as the incoming currents were finely divided streams, they would, in passing toward the floor, twenty-five feet distant, become so nearly the temperature of the room as to become harmless as to temperature. I was, however, disappointed and the device proved useless; it might have worked if the heated

air had gone out at alternate apertures with those at which the cool air came in, but the probabilities are that the outgoing currents massed at one-half the plate and the incoming at the other, and the latter joining together as they fell, made the operation of the ventilator about the same as if no perforated plate had been used. Very likely, if I had carried alternate tubes to within eight or ten feet of the floor, with the hot-air apertures between the pipes, there might have been better success in the result.

I was lately shown another plan for relieving an oppressive lecture-room of heated air and supplying it with fresh air, but it too was a failure, and I consider all attempts at ventilation and air supply as misspent means and labor, unless they comprise ample facilities for warming or tempering the inflowing air when the weather is cold.

Coming now to the consideration of the methods of heating rooms and buildings, the use of stoves and direct radiators placed in rooms must be discarded, because of their furnishing no air supply to the rooms. Some advantages have been supposed to arise from radiated heat, because affording sensible warmth and admitting of cooler air for breathing, but less stress is now laid upon this than formerly, and it is of no practical account for large audiences.

Openings are sometimes made adjacent to the ordinary direct steam radiators in rooms, but their action is uncertain, as, at times when the wind is unfavorable, the air will pass out through the openings instead of into the rooms, and when the weather is very cold and the wind favorable for the air supply, the portion of steam surface presented to the current of air is inadequate for its warming, and the aperture is closed because the room cannot be kept warm enough on account of the cold current.

Hot-air furnaces are an advance upon stoves, because all the heating done by them is accompanied by a volume of air of greater or less amount, and for years to come, for many private and some public buildings of moderate size, hot-air furnaces will probably be used, and within reasonable limits may answer a fairly satisfactory purpose.

The besetting shortcoming of the day, however, is that the furnaces for buildings, whether private or public, are altogether inadequate in capacity for the work that ought to be done, and the air supply to the furnace and the flues for conducting the air to the rooms are seldom half the size they should be. The consequence is that many buildings cannot be warmed in zero weather by their furnaces, the air supply is never sufficient for the occupants, and as the furnaces are often necessarily forced and without water evaporation, the air is supplied at a high temperature, and the floating particles in the air being burned upon the overheated surfaces, the quality of the air furnished to the living rooms is baked, unpleasant and unwholesome.

It will be urged that larger furnaces will cost more to erect and run, which is true as to first cost, but, within certain limits, not true as to maintenance, because it is quite as expensive to run a small furnace beyond its capacity as it is to run a furnace better proportioned to the work.

In building flues for inflow and outflow, it is not well to build smaller than twelve inches square because of friction, the total area, I think, should equal one-third of a square foot for every 1,000 cubic feet of contents. This will bring controversies between owners and builders; but I have a hope, future owners and builders will be willing to plan their flues first and adapt the balance of the house to them. In large buildings flues eighteen inches square are a good size.

With furnaces or any other method of heating, there should be provision for changing the temperature of separate apartments, without such regulation of the furnace as inconveniences other parts of the house, or the closing of registers and restricting the air supply. This has seldom been attempted. Two cases of private houses are within my knowledge, in which the air was taken at will from the top of the furnace or from the bottom, but the mechanical work was at fault in one case and the flues too small in the other to be wholly successful; but these are matters which experience can quickly cure.

In the case of lecture or other rooms of sufficient size to require one or more furnaces for their especial warming, a

simple device will greatly relieve the overheating. This I accomplished for a meeting-house in Philadelphia by having large openings made in the furnace chambers above the drums and causing the doors to these openings to be worked by the Johnson heating regulating apparatus, which at the same time worked the draught of the furnaces.

Thermostats placed in the meeting-room, being set at a given point, the operation is that when the temperature of the room rises above this point, the draughts of the furnaces are closed, thus reducing the fire, and air is admitted to the furnaces above the drums and passes up into the room only partially heated until the temperature falls to the regulation point, when the cool-air opening is then closed, the air follows the usual course through the heating chamber and the draught is put on the fire.

The foul-air ventilation is at the ceiling, and the apparatus works very well for an appliance made to an ordinary furnace; and all lecture-rooms, heated in the usual way by furnaces, could be greatly improved in this way at a moderate expense, although no furnaces of the old patterns are probably of sufficient capacity and air supply to meet the proper demands of an audience.

The best furnaces for capacity and the best arrangement of heating and ventilating by hot-air furnaces that have as yet come to my knowledge, are the Rutan hot-air furnaces and the Rutan arrangement of flues, furnished and planned by Smead, Wills & Co.

These furnaces are so arranged that the cold air passes at will under the furnace or through it, or partially in each way, and the sizes of the flues are in accordance with a suitable provision for the ventilation of the building.

With the ordinary steam apparatus, indirect heating or placing the radiators at the base of flues is relied on for the purpose of warming the air before it enters the room, and the flow of air through the flues is relied on for the air supply. The current is thus dependent somewhat upon the amount of steam supply to the radiators, and somewhat upon the suction or pull of the foul air or ventilating flues of the building.

This indirect system answers partially well for dwellings and rooms of but few occupants, but is totally inadequate for the wants of class-rooms and rooms of many occupants, as the diminished temperature required when the rooms are full curtails the ascending force where the most air is wanted, and moreover, as the outside temperature approaches the inside requirements, all the systems of natural draughts depending upon the difference in weight of the outside and inside columns of air completely fail of their desired efficiency.

Without dwelling at greater length in illustrating these points, because they are probably obvious to all who of later years have examined the subject and have had experience in contending with the practical solution of heating and ventilating problems, I think it may safely be stated that the time has come for, and the state of sanitary enginering education warrants, the abandoning of all reliance upon natural draughts in the ventilation and air supply of all large buildings or rooms of crowded occupancy of whatever character, private or public, with perhaps occasional exceptions of single rooms opening directly at the top.

This point being reached, there remains only the consideration of its alternative, or forced ventilation.

Forced ventilation may be secured by artificially heating the exhaust flues or shafts, or by exhaust fans, either of which plans will withdraw the foul air from the respective rooms, and thus induce an inflow of pure air to the rooms at the inlet. In some cases, perhaps, this is the most convenient method that can be adopted.

A minus condition to a room, however, will induce currents from all openings, as well as those intended for the air supply; but the leakage from windows and doors of cold air, as well as the quickening of the currents of air cooled by direct contact with the windows and walls, are undesirable.

The minus condition may also, in many cases where the inlets and outlets of the rooms cannot be placed advantageously, result in a direct passage of the pure air to the outlets without distribution through the room, thus making thoroughfares of wholesome atmosphere, but leaving great masses of stagnant air between them.

Ventilation shafts, if of much size, and of a height to be effective, are expensive, and the cost of maintaining the upward current by applied heat is not economical, for the experts tell us that one pound of coal will accomplish twice the work in moving air when expended as power that it will accomplish when expended as heat; and, further, the construction of exhaust shafts is often incompatible with the convenient arrangement for large buildings, excepting by increasing the number of them and largely adding to the cost of construction.

On the other hand, a plenum condition of a room, or that resulting from having the fresh air forced into the rooms, obviates some of the disadvantages of the minus or exhaust system, for the pressure being upon all parts of the room, the cold air is pressed against at all the cracks or leaking places of doors, windows or elsewhere, instead of being encouraged to enter; and, again, an open door from either out-of-doors or a cooler hall or room, is not the means of having rude blasts of shivering air enter the room, disagreeable and dangerous to the inmates. For hospitals and other places, where it is desirable that even small portions of air from a room should not be allowed to pass into other parts of the building, it may be needful to assist the exhaust flues of the rooms by artificial means; but for all ordinary buildings, such as school-houses, lecture-rooms, etc., when properly arranged with vent for each of the rooms, the plenum system will, without doubt, be sufficient and most desirable.

Fans have long been used for producing forced ventilation in buildings and keeping the rooms in the plenum condition, and if properly constructed and proportioned to the work, and properly supplemented with suitable air conduits, are the best means of accomplishing the object in view.

In many large buildings it has been the practice to use a simple wheel of large diameter, with curved flanges or vanes at the circumference displacing large volumes of air, and driving the same into basement corridors or ducts, from which the air passes through the radiators at the base of flues leading to the various rooms of the building.

As a rule, the current of air from wheels of this character forcing the air into large corridors becomes of very little effect at a comparatively short distance from the wheel, partly from the construction of the wheel not being the best for exerting pressure upon the current, partly from the leakage of the duct or corridor, and partly because from the size of the corridor any pressure from outside winds upon exposed apartments would be sufficient to drive back the currents and prevent them from entering the rooms, by cushioning upon the air in the corridor or the supplying duct.

Practically, therefore, the fans thus constructed and arranged are of little value, and in one instance of a large institution within my knowledge, the superintendent ceased to use the fan, and made openings at intervals into the corridor for an air supply, thus returning to the ordinary indirect heating system depending only upon natural draughts. Buildings arranged in this manner would be very much improved by constructing a by-pass or valve work at the base of each flue, by which the air could at will be made to pass through the radiators or around them for the controlling of the temperature in the rooms above, or if a simple regulating apparatus was provided by which the steam supply to the radiators governed the temperature.

The most effective apparatus that has yet been devised for heating and ventilating large buildings of which I have any knowledge, is by the use of an ordinary pressure blower attached to a heating chamber through which it forces the air, and from which the heated air is conducted in air-tight piping of proper proportions, branching off to the various rooms in the building.

For the heating surfaces of the heating chamber the usual steam pipes and coils will answer, but the heating chamber which much more favorably impresses me is one recommended to me by George W. Storer, of 149 North Third Street, Philadelphia, to whom I am indebted for having first called my attention to the efficiency and economy of applying to schools and public buildings the system I am now attempting to describe and recommend—a system

which, it is to be observed, has been generally adopted of late years for warming large industrial establishments, but without the detail needful for use where the buildings are divided into many apartments.

The heater built and used by G. W. Storer consists of two tiers of the ordinary pin radiators, through which the air to be warmed is forced by the blower.

There is an advantage in banking the heating surfaces of a building in one mass, as it puts the control of the steam upon a single valve, if desired, rather than upon a multitude distributed all over the building; for although this does not relieve from care of blast gates and registers at the respective rooms, the care of management of the latter and the cost of repair are much less than for steam valves.

I am also disposed to believe that the loss of heat in carrying the heat to a distance is less than by a ramification of steam pipes all over the building, notwithstanding the superior carrying power of steam, but I apprehend there has not sufficient experience been had to determine this point with certainty.

Less radiating surface for the cubic contents of the building is required when the radiators are concentrated in a chamber arranged as just described than when they are distributed around at the different rooms, and the mains and returns are dispensed with, and the cost of steam fitting much reduced. The total cost of the heating plant of a building by this method, notwithstanding the expense of blower engine and piping for the hot-air ducts, is but little if any more than a plant of the ordinary type of indirect steam heating.

The reason that less heating surface is required for the same work is because a radiator filled with steam under ordinary arrangement can only affect the temperature of the quantity of air which comes in contact with it, but is capable of heating a much larger volume than comes to it when influenced only by natural draughts.

An illustration of the capacities of these pin radiator heaters may be mentioned in the results of experiments in

1887 with a small model in which each tier consisted of three pin radiators, or six in all, the air being forced with a small blower of six-inch outlet.

When the air was forced through the heater under a pressure of four and one-half inches of water, or say with a velocity of over 7,000 feet per minute, the temperature of air was raised from 20° to 163°, or 143°; and with the air pressure of two inches of water, or over 5,000 feet per minute, the temperature was raised to 180°, or 160°. High-pressure steam, or forty pounds to the square inch, was used in both these experiments.

With ten pounds of steam on the heater, and air pressure two inches of water, the temperature of the air delivered was 147°, or 127° of elevation of temperature.

A model of this size is not to be altogether depended upon for calculations of a large plant, but the great heating capacity of the heater properly proportioned cannot fail to be apparent, as also the fact that if two tiers of pin radiators are kept filled with steam it will be impossible for air to get past the radiators at any velocity for convenient use for heating purposes, without being sufficiently warmed.

In a larger heater containing sixteen radiators in each tier, I purposely covered one-half the radiators as well as could conveniently be done in order to test certain points respecting the retardation by friction, thus exposing only eight radiators in each tier to the air supply of sixteen inches in diameter.

With so small a radiating surface and so large a pipe, the temperature was raised 118° with an air pressure of one and one-half inches of water, or a velocity of over 4,000 feet per minute; and 130° with one-half an inch pressure, or velocity of (say) 2,500 feet per minute, or a delivery of (say) 3,000 cubic feet per minute—the outlets not being quite equal in area to the sixteen-inch opening. This experiment must not be taken for a basis of close calculations, because the radiators which were covered over were filled with steam at the same time, and probably contributed something to the temperature, although little or no air passed through them.

Making all allowances, however, and counting the heating surface of the pin radiator at practically eight to eight and one-half square feet, though nominally greater, the heating power is very apparent.

In another series of experiments with the heating apparatus, in which the full capacity, however, was not tested, the water of condensation was weighed.

The aggregate experiments extended over an hour and three-quarters, the temperature was raised 100° on an average, the quantity of air passed through the heater was 472,508 feet, and the condensation was 558½ pounds of water —or reducing this to an hour, the volume of air was 270,000 cubic feet and 319 pounds of water.

Allowing the very low estimate of six pounds of water to one of coal, we have fifty-three pounds of coal as the equivalent of work, or in other words, one-half pound of coal per hour raised 2,700 cubic feet of air 100° in temperature. This is a very fine showing, and six pounds is a very small allowance for the evaporation power of the coal, but there must be a liberal counting on radiation of heat at the boiler before the steam reaches the heating chamber.

Heavy pressures of air are not desirable for ordinary purposes of heating and ventilation, both on account of the strong currents to be handled at the rooms and the apparent loss of heat at the point of delivery from expansion into the room. This, perhaps, is not serious, but care must be taken to have ample capacity of blower and engine for maintaining an air supply in time of storms, when the pressure on exposed sides of a building tends to neutralize the air supply for that part of a building. This difficulty is well known in ordinary methods of heating, and it is owing to the inability of the old-fashioned wheel fans heretofore described, and the modern radial fans known as the wing-fan pattern, to maintain a pressure upon a building, that pressure blowers, such as are constructed for heating and ventilation purposes, are to be preferred, and in fact they are, I think, the only kind of sufficient reliability to be recommended.

Heating plants have long been designed and used essen-

tially upon the plan here recommended, but have not been entirely successful, probably solely through the want of liberality in their proportions, but these are defects which observation will make apparent. It will also require time to bring the system into favor, as it will probably be condemned—as it has been by those, who, upon greater knowledge of its merits, have adopted it.

Future experience will, no doubt, greatly perfect the details; but enough is already known to warrant the venturing upon suggestions.

I recommend taking a uniform pressure of one-quarter of an ounce as the force of the air supply in the main piping, and having the blower capacity per minute at that pressure equal to one-tenth the cubical contents of the building to be heated and ventilated.

In other words, for a building of 500,000 cubic feet contents, the blower should deliver 50,000 feet per minute when running at a speed equivalent to one-quarter ounce pressure, and taking for the equivalent velocity of the air 2,000 feet per minute at the points of exit as the basis of all calculations for the delivery of volume instead of the theoretical velocity of 2,584 feet.

The blower should not be calculated upon this basis at its maximum capacity, but should be capable of being driven at a velocity increasing the air supply to an ounce or more pressure if required.

The basis herein recommended indicates a capacity to change the air in the whole building every ten minutes on a normal speed, which, while not covering all that may be wanted in special rooms, is so far in advance of the prevailing usage as to answer for a beginning at this stage of the science, especially as the surplus power can be held as a reserve.

In practice, the whole of a building is seldom used at once, so that the full capacity will seldom be invoked, and the rooms not in use will, of course, not be drawing upon the air and warmth supply, and hence special rooms may be changed once in five or three minutes if so arranged.

It is a property of air currents from a blower that the

closing off of part of the outlets does not clog the blower, as it really runs the easier, the wheel in the case simply slipping in its own air supply; and as the exhaust steam of the engine is utilized in the heating chamber, the cost of producing the currents and pressure upon the building is very slight.

Great care is needed in the piping for this system, as the engineers and architects accustomed to planning and the mechanics skilled in the workmanship are at present very few; the tendency of the former being to pipe on too small a scale, and the latter to be abrupt in their angles and rough in their work.

As the details must vary with every building, only general principles can be enunciated, and these may require modification in special cases, but the following may be of service as a guide:

The blower being of the capacity indicated, the main pipes leading from it must maintain the full cross-section of the area of the outlet of the blower, until the diverging branches to the various rooms of the building have reduced the demand upon the main, when the main may be reduced in section, care being taken not too reduce too rapidly; small branch pipes of great length are quite undesirable; it is better to so divide the mains as to keep as great a mass of the heated air together as circumstances will allow.

The number of branch pipes to each room will depend on the size and circumstances of the room. One pipe, of eleven inches diameter, discharging at one-fourth ounce pressure would deliver over 1,300 cubic feet per minute, but two pipes of eight inches each would deliver about the same, and by being at different points in the room, secure a better distribution. Unless for small rooms or closets, less than six-inch outlets are not desirable.

The area of the branch pipe or pipes to a room must not be less than one square foot for every 20,000 cubic feet capacity of the room, for changing the air once in ten minutes, and of course must be greater for crowded roams.

As a rule, the blast pipes should not enter directly into the room, but should open into flues or pipes at the rooms

of four times their area, in order to reduce the velocity of the inflow at the room. This refers more particularly to registers or inlets at the sides of the rooms, eight feet from the floor, as with this arrangement I have had no inconvenience whatever from currents, although the smaller pipe within the flue delivered air at the quarter-ounce pressure, or 2,000 feet per minute velocity.

Where this enlarged flue cannot be had for expanding the current, it may, however, do to run some risks of currents. Thus, in a certain lecture-room not originally constructed for this system, I have, through the flues, as I found them, driven three overhead streams of air, delivering not less than 10,000 feet per minute, at a velocity of 2,500 feet per minute, the currents reaching to the opposite wall, fifty feet distant, with but a moderate annoyance from currents in the room; and this annoyance a little change of delivery places will probably remedy.

Round pipes are better than square pipes, a circular pipe one foot diameter delivering air more satisfactorily than a pipe one foot square, with the saving both in mechanical construction and in the material proportional to the relative circumference, or nearly twenty-five per cent.

Corners must always be turned on a perfect curve. I have seen the delivery of pipes almost destroyed by an abrupt turn, although the outlet area was maintained. It follows also that branches must always diverge from mains at an acute angle, and never at 90°, to ensure full delivery.

For large audience rooms liable to be closely packed, the best method of entering the fresh air is through the floor by small orifices, so numerous and of such area that a steady flow passes steadily upwards, without serious draught, to the outlets at the roof or ceiling.

Many audience chambers, however, cannot have the use of the basement or room beneath for the necessary piping or reservoir of air, and in that case, recourse must be had to the sides of the room and the outlets above the heads of the occupants eight or ten feet from the floor, as may seem best, according to the height of the room.

As all machinery is liable to accident, the heating

chamber and blower should be duplicated in cases where a delay in heating would be inconvenient. Thus for a building of 1,000,000 cubic feet capacity, instead of one large wheel of 100,000 cubic feet per minute capacity, two of 50,000, with their respective heating chambers, would be better, placing them contiguous to each other, and arranging so that one could do the work of the other when temporarily necessary. This could readily be done by speeding up above the regular speed, and being satisfied for the time with a little less air supply as a whole.

The fan and heater and piping constitute the main portions of the plant, but other details are of great importance for controlling the temperature of the rooms to be heated without varying the air supply.

In the case of large audience rooms, the simplest plan would be to let one blower ordinarily be in service only for that room, and regulate the temperature by the steam valve of the heating chamber, either with automatic apparatus controlled by a thermostat in the chamber, or, if an apparatus is used which will indicate the temperature of the chamber in the engine-room, the hand of the engineer can, without much care, keep a steady temperature.

This, however, will not be available where several or many rooms are to be heated by the air from the same main pipe.

To meet this case in a building where the basement was not required for other purposes, I devised a simple application of the principle of induction.

In this building the main warm-air pipe starts from the heating chamber with a diameter of fifty-four inches and passes through the central corridor of the basement, branching out to flues on either side and diminishing in diameter to about eighteen inches at the extreme end.

The branch pipes of six, eight and more and less inches enter the flues for the rooms and terminate in the base of these flues with a short pipe above the elbow, the hot-air pipe being furnished with a blast gate worked by a lever in the class-room. The flue is about four times the area of the blast pipe, and at the base on the other side of the corridor

hall has a valve door, which, when open, admits air from the basement around the blast pipe.

The cool-air valve is also worked by a lever in the class-room, and the flue opens into the class-room eight feet from the floor.

The air in the main pipe is intended to be kept at a steady pressure of one-quarter of an ounce and at a temperature according to the weather to afford sufficient heat in any part of the building.

With the blast gates wide open, a flow of warm air enters the room in a volume sufficient to change the volume of the room once in ten minutes, but when the room becomes heated to whatever degree is desired, say 68° or 70°, the hot-air pipe is slightly closed and the cool-air valve is opened.

By this operation the warm air is slightly curtailed, but, as it is still rushing in with considerable force and is surrounded with cooler air from the opening of the cool-air valve at the base of the larger flue, by the principle of the injector or by induction, it carries up a greater volume than has been shut off from the warm-air pipe.

It requires but little care to so adjust the valves as to vary the temperature at will, without diminishing the volume.

This plan, however, would not be available in buildings in which the basement was wanted for occupancy, or where, owing to surrounding buildings or for other reasons, it was not easy to obtain the supply of cool or tempered air at every flue.

These contingencies can be met by doubling the piping system, carrying hot air through one system and tempered air through the other, and entering the branches from both into the flue or directly into the rooms and regulating the inflow by suitable valves.

In this arrangement the heating chambers must be arranged to supply the air at the respective temperatures required.

Flues are the better for being in inside walls, rather than outside, and no fears of good distribution need be enter-

tained, because both inlets and outlets are on the same side of the room.

Where the walls do not admit of good-sized flues, offsets in the room should be endured rather than small flues.

Offsets may be reduced to a minimum by using metal.

Registers should be dispensed with when the inflow is regulated by other valves, and an opening with a neat border and lining will soon be as sightly to the practical eye as registers.

Fans should be run by their own engines, in order that the air delivery may be controlled according to the occupancy of the building, without reference to connections with other machinery.

Moisture should be added to the air after warming. In one case where I failed of sufficient quantity with a large surface of boiling water, I found a steam-jet to answer.

Specially exposed rooms must be borne in mind and specially provided for. Thus in an institution, the newest part of which is warmed on the system described, the temperature was not satisfactory for three rooms very much exposed, the pipes to which were small and carried in outside walls, but all defects were cured by an increase of the air supply.

In conclusion, the object of this is more for the purpose of inciting investigation and much-needed improvements in the ventilation of public buildings, and places where audiences gather and business men spend their time in business hours, than to present a basis for technical contention.

The methods particularly recommended may not be applicable to all existing buildings, though there are but few buildings in and near Philadelphia, however recent their erection, but that greatly need improvements in ventilation. With those who cannot suspend their judgment long enough to understand what is being explained to them without expressing either an adverse opinion or a description of some other system, it is a thankless task to discourse, but those who have worked sufficiently in the practical work of heating and ventilation to realize the real intricacies

of the problems presented, and which vary with every building, everything bearing upon the subject is patiently considered, and with an interest that pertains to seekers for further knowledge.

At the end of ten years, after taking an interest in matters pertaining to ventilation, I felt I was further back than at the beginning, and at the end of twenty years had made but little progress. At the present time, some ten years later, I am only at the point of starting fresh, hoping, however, to give some impetus to the cause, and particularly to incite others to go on to more perfect work.

ON THE LONGITUDINAL RIVETED JOINTS OF STEAM-BOILER SHELLS.*

By JOHN H. COOPER.

The initial statement to the English Lloyd's rules for steam boilers is embodied in the following words: "The strength of circular shells to be calculated from the strength of the longitudinal joints," which assures us that this part of the boiler should be properly proportioned.

To these rules a memorandum is added: "In any case where the strength of the longitudinal joint is satisfactorily shown by experiment to be greater than given by this formula (Lloyd's), the actual strength may be taken in the calculation."

Later on, Lloyd's rules (under the head of "Periodical Surveys," regarding the examination of boilers after they have been several years in service) say: "The safe working pressure is to be determined by their actual condition."

These statements lie in the line of practical efficiency, and point to the necessity of providing material in accordance with the requirement of the load to be carried.

* Read at the Nineteenth Meeting of the American Society of Mechanical Engineers, and revised by the author for publication in the JOURNAL from advance-sheets of the *Transactions*.

Any one who takes the trouble to collect and compare data on this subject cannot fail to notice the great disparity of rules for determining the working pressure permissible for boilers.

The case is clear by simple reasoning on the data collated, that boilers are held together, it would seem, more by conformity to rule than by the materials of which they are made.

But, of course, the true course to pursue is to give to each member its proper allowance of section, in order that the components of the joint shall have an equal chance under strain according to its resisting power.

The diminished strength of the shell of a boiler by the longitudinal joint is well known, and it becomes good engineering so to proportion its parts as to obtain the greatest strength possible within the limits of practical economy.

When it became necessary to assure themselves confidently of the permanent safety of a structure composed of plates held together by rivets, engineers were not long in finding out that a certain allotment of rivet section to plate section at the joints was necessary, and that these sections were found to be nearly equal in the strongest joints.

The experiments of Fairbairn, conducted in the year 1838, proved that—"the sectional area of the rivets in a joint was nearly equal to the sectional area of the plate through the rivet holes."

Subsequent experiments by Clark on riveted plates for the Britannia and Conway Tubular Bridge fully corroborate the above statement; his conclusion was: "The collective area of the rivets is equal to the sectional area of the plate through the rivet holes."

This relation of the components of the joint in course of time became embodied in the English Board of Trade rules and in Lloyd's rules now in force, regulating the construction of steam boilers. It also forms the basis of the Philadelphia steam-boiler inspection ordinance, first formulated in 1882.

Referring now to those rules only which relate to the proportions of the longitudinal joints of the cylindrical

shells of boilers, we are prepared to say they may be most conveniently presented by the following notation and formulæ:

NOTATION.

A = Percentage of punched plate to the solid plate.
B = Percentage of driven rivet section to the solid plate.
C = The pressure in pounds per square inch, which the boiler is allowed to carry.
a = Area of driven rivet, or rivet hole.
d = Diameter of rivet hole.
n = Number of rows of rivets.
p = Pitch of rivets.
t = Thickness of plates.
R = Radius of boiler shell.
S = Ultimate shearing strength of rivets in pounds, per square inch of section.
T = Ultimate tensile strength of plates in pounds, per square inch of section.
f = Factor of safety.
E = Limit of elasticity in the plates in pounds, per square inch of section.
$\%$ = Percentage of joint strength.

The least of A or B should be inserted in the formula C.
All dimensions in inches.
The notation and the formulæ mutually explain each other.

$$A = \frac{p - d}{p} \tag{1}$$

$$B = \frac{a\,n}{p\,t} \tag{2}$$

$$C = \frac{t\,(A \text{ or } B)\,T}{R\,5} \tag{3}$$

These formulæ are intended exclusively for the guidance of the inspector in ascertaining the exact strength of the joints in the boilers which come under his care, and which enable him to determine the working pressure of steam

allowable under the rules. They do not, however, enable the boiler-maker to determine directly that proportion of pitch which he should use with any given plate thickness and rivet diameter, in order to secure the strongest joint and which will also pass the highest inspection.

To secure these results, the following simple formulæ were devised by the writer (early in 1882), in which the notation given above is similarly employed, and which may be thus expressed.

For single riveted joints, when iron plates are secured by iron rivets and when the plate thickness and rivet diameter are given, if it is desired to find a pitch that will secure equality of plate and rivet section, the formula will be:

$$p = \frac{a}{t} + d \tag{4}$$

This plainly means that the pitch is equal to the area of the rivet hole, divided by the thickness of the plate, and to the result of which the diameter of the rivet hole must be added.

For multiple riveted joints, when iron plates are secured by iron rivets, the same formula is used, with the addition only of n, representing the number of rows of rivets, thus:

$$p = \frac{n\,a}{t} + d \tag{5}$$

The different resisting power of equal areas of section, as many times found by tests of the shearing stress of the rivets and the tensile stress of the plates, is not taken into account in the make-up of these rules. They are treated in all cases as equals under the strains of continued use. That is to say:

The Philadelphia boiler ordinance and the English rules alike impliedly declare: The shearing strength of the rivets is just equal to the tensional strength of the plates per square inch of area in boilers made of iron plates and iron rivets.

If any one takes exception to this treatment of the two strains, the formulæ permit him to introduce his own figures of difference into their make-up, by which he can get a result

in accordance with his own belief; but of the mathematical base, embodied in the formulæ, we are sure.

For single and multiple riveted joints, when steel plates are secured by iron or steel rivets, the relative resistance of the plates to tension and of the rivets to shear must be inserted in the formula.

First, let us assume, as the rules for inspection have done and do in all cases, that, area for area subjected to stress and acting together, iron plates and iron rivets are equal in resistance.

The "Best" Staffordshire iron boiler plates will stand 48,000 pounds T per square inch of section; but the Board of Trade and Lloyd's limit all best iron plates and rivets alike to 47,000 pounds.

The Philadelphia ordinance will pass iron plates which have shown on test a T of 50,000 pounds per square inch, but will allow no more whatever the plates may show, and will give full credit to a joint in which the driven rivets have equal section to the punched plates.

And yet we well know it to be a matter of fact that the shearing strength is less than the tensile strength of the same material.

Mr. William H. Shock's experiments on American iron gave as a mean for single shear 41,033 pounds per square inch, and 78,030 pounds for double shear, these experiments being made upon iron bolts in a shearing device which did not include the uncertain element of friction by the rough surfaces of the plates when bound closely by the rivets of a riveted joint made in the usual way.

When iron rivets are used with steel plates they are accepted under the rules for just what they are worth under shear and no more. The English rules say: "Iron rivets in steel boilers should have a section of $\frac{13}{8}$ of the plate section." Steel rivets must be calculated from their actual strength to resist shearing; and for these the fraction $\frac{28}{23}$ will express the larger area they must have to the plates with which they are used to make joints, simply because steel plates show an ultimate T of twenty-eight tons, and steel rivets an ultimate S of twenty-three tons per square inch of section.

The old rules published by Fairbairn, and used by him and by many boiler-makers since, are obsolete now, in the light of the later method of proportioning joints and the laws which sanction their use, although he furnished the first material for the base upon which this law has been built.

From an extended list of all iron single joints, proportioned on the principle of equality of sectional areas, the percentage of joint strength to the solid plate will reach to ·64 and in double joints to ·78 and be practically tight under pressures up to, say, 100 pounds of steam per square inch—a material increase over the oft-quoted figures of ·56 and ·70, originated and recommended by Fairbairn.

If we accept the inspection laws referred to, assuming even results of the two strains, then Rules 4 and 5 will find the proper pitches for boiler joints made of iron plates and iron rivets; but in composite boiler shells, the introduction of symbols representing the actual powers of resistance of the components, will be necessary. We will then have for double or multiple joints:

$$p = \frac{n\ a\ S}{t\ T} - d \qquad (6).$$

which can be applied also to an all-iron joint or to joints made of other materials than the usual iron and steel.

In formula 6 may be inserted the elastic limit E of the plates to tension, instead of their ultimate tensile strength, and with this should also be inserted the stress at which the shearing of the rivets begins, together with a factor of safety corresponding to the requirement of these important factors.

If we desire to find the pitch of the rivets, when the rivet diameter and a certain percentage of joint strength are given, we may use the following formula:

$$p = \frac{d\ \ \%}{(100 - \%)} + d \qquad (7)$$

This does not include the thickness of the plates; it relates only to the proportion existing between the distance

from centre to centre of the rivet holes and the space between the holes.

Other convenient formulæ are readily obtained from *A*, *B* and *C*, by transposition. If, for instance, it is desired to know the *S* to which the rivets are exposed in any particular case after all the elements have been obtained, the formula will take this shape:

$$S = \frac{C \times R \times f}{t \times B} \tag{8}$$

and will give the pounds per square inch of cross-section to which the rivets are subjected in the seam by the steam pressure *C*, which has been obtained by the Ordinance formula.

The *rivet hole* determines the size and measure of the rivet after it is driven, because it is then filled by it; and in making calculations with the aid of these formulæ, the trade sizes of the rivets *must not* be taken.

In punching holes for rivets in boiler plates, it is the usual practice to use punches $\frac{1}{16}$ of an inch greater in diameter than the trade diameter of the rivets, and it is also usual to make the dies which are used with the punches $\frac{1}{32}$ of an inch larger in diameter than the punches to be used with them. The result of this method is to make conical holes in the plates, corresponding to the sizes of punch and die.

If the punched holes are net to the dimensions of the punch and die here given, and if the material of the plate immediately around the hole has not suffered in the act of punching, then the proper size of holes to be used in the formula would be the *mean* diameter of the conical holes so made, instead of $\frac{1}{16}$ of an inch larger than the punch, as they are usually assumed to be.

It is well known, however, that the material of the plates bordering the holes is weakened by the detrusion of the punch; to what distance this reaches from the surface of visible separation of the metal may not be definitely known, and must necessarily be different with different materials and punches, but it is certain to be a small measurable distance into the plate around the hole.

If we take the diameter of the punched holes to be equal to that of the die, we will not be far from the actual state of the case, especially as some of this disturbed metal is removed by the reamer or crushed by the drift-pin.

We are safe in this assumption in so far as the ultimate strength of the joint is concerned, because, as usually happens in rupture, the plates give way, while the rivets rarely fail; and again, the plates suffer loss of substance by wear and waste, while the rivets are preserved against deterioration, and, therefore, the initial strength of the plates ought to be favored.

In view of these facts, the suggestion is here made that when we wish to determine pitches from given plates and rivets, that we use the *greater diameter* of the punched hole, whatever that may be, for the quantity expressed by a in all of these formulæ, and that we assume the rivet diameter to be that of the lesser diameter, or reamed-out diameter of the rivet hole.

The result of this apportionment of the material will be effectively to strengthen the plates, which all experience has proven to be necessary; so that while this decision appears to be against reason and the isolated facts of experiment—the resistance to shearing always proving less than that to direct tension in the same material—it must constantly be borne in mind that the strain on the plates and rivets are not *direct* in the ordinary lap-joint as they are used in a boiler, the plates being subjected to some transverse strain while under tension, and the rivets to some tensile strain while under shear.

Strictly speaking, the plate loses what is punched out of it, together with the metal destroyed around the punched hole, and the rivet gains by whatever increased diameter it gets in the process of riveting. They should be estimated upon what they actually are when the joint is made up.

On LAPACHIC ACID and ITS DERIVATIVES.

By E. Paterno.

[*Communicated by Dr. W. H. Greene, at the stated meeting of the Chemical Section, held June 18, 1889.*]

In the last number of the *American Chemical Journal* (**11**, No. 4, April, 1889, p. 267) which reached me yesterday, I have read an important note by W. H. Greene and S. C. Hooker, in which is proved the identity of the coloring matter of Bethabarra wood with lapachic acid. In ending their note the authors propose to study lapachone and suggest that certain reactions observed by them lead to the belief that this compound has not the constitution provisionally assigned by me in 1882.*

I must draw the attention of these two chemists to the fact that in my memoir, after having stated that the constitution of lapachone was perhaps the most difficult and important point to determine, I terminated by saying, that all my considerations had a very limited value and I dwelt on it but a moment, with the sole design of showing the importance and the range of the argument of which I had undertaken the study.

It is indeed true that since 1882 I have published nothing on lapachic acid. I have been occupied with other matters, it has been difficult for me to obtain first materials, and I did not desire to publish the results in parts, especially when I had reserved the right of continuing the research. However, that I have never abandoned the work is shown by the fact that in my research on Raoult's law, published conjointly with Nasini in 1886,† we proved that lapachone is not a polymeride of lapachone as I at first supposed, but that it corresponds to the simple formula $C^{15}H^{14}O^{3}$, and I said that while the polymeric quinones so far studied are brown substances, only slightly soluble and having fusing points much higher than the corresponding quinones, these great differences in external characters are not observed between lapachic acid and lapachone. Since that time, as I have besides announced a few months ago,‡ I have continued

* *Gazzetta Chimica*, **12**, 337. † *Ibid*, **16**, 262. ‡ *Ibid*, **19**, 3.

this research with greater industry, and by applying Raoult's method I have shown that the acetyl derivative of lapachic acid fusing at 131–132°, for which I had advanced a complex formula, corresponds rather to that of a diacetic derivative of lapachic acid or of lapachone or more probably another isomeride of this substance; and in a series of researches, that I may say are complete and which were in part made together with Sig. Minimi, I have entirely reconsidered the study of those derivatives of lapachic acid of whose constitution I entertained doubts, and in particular lapachone, the diacetyl derivative and the magnificent substance crystallizing in splendid bronze-red laminæ. Of lapachic acid and lapachone we have studied the oxime and hydrazin compounds, we have obtained the quinone corresponding to the diacetyl derivative, we have prepared and studied the triacetyl derivative, corresponding to the reduction derivative of lapachic acid, the compound of lapachic acid with thiophen has been prepared, and in this manner we have collected together a considerable number of facts which completely elucidate the constitution of lapachone and many other derivatives of lapachic acid.

I am sure that Messrs. Greene and Hooker will, after what I have exposed, allow us time to publish our labors and desist from the further investigation of lapachic acid derivatives, at least until after the publication of our researches.

ELECTROLYTIC SEPARATIONS.

By Edgar F. Smith and Lee K. Frankel.

[*Read at the Meeting of the Chemical Section, June 18, 1889.*]

I. SEPARATION OF CADMIUM FROM COPPER.

The results obtained in the electrolysis of cyanide solutions of mercury and copper, as well as the knowledge gained from our experiments in separating cadmium from zinc, induced us to try whether it would be possible to effect the evaporation of cadmium from copper in cyanide solution. The only electrolytic method pro-

posed for the separation of these metals is that recommended by Smith (*Am. Chem. Journal*, **2**, 42), in which solutions containing a definite amount of free nitric acid were employed. We experienced no difficulty in making a complete separation, after ascertaining the proper current strength. The conditions most favorable to the separation were essentially the same as those recorded in our former papers, viz: a dilution of 200 cc.: 5·5 grammes of potassium cyanide in each experiment, and a current generating ·28 cc. oxy-hydrogen gas per minute. Time sixteen to twenty hours. The results obtained were as follows:

Cadmium present.	*Cu present.*	*Cadmium found.*
	I.	
·2426 grs.	50 per cent.	·2420
	II.	
·2318	50 per cent.	·2331
	"	·2309
	"	·2315
	III.	
·1024	100 per cent.	·1028
	"	·1019
	"	·1020
	"	·1032
	"	·1033
	"	·1034
	"	·1014
	IV.	
·2046	100 per cent.	·2034

Copper was not found in any of the deposited cadmium, nor did we discover any of the latter metal in the filtrate containing the copper. The cadmium deposit invariably showed the gray color characteristic of it.

II. ACTION OF THE CURRENT UPON METALLIC SULPHOCYANIDES.

It is well known that in the electrolysis of the sulphate or nitrate of manganese the oxide of this metal separates upon the positive pole. We have found that if an excess of potassium sulphocyanide be present no such deposition occurs, but, on the contrary, the metal itself will separate as

a grayish white, compact deposit upon the negative pole or the vessel attached to it. The addition of a sulphocyanide to the manganese solution undergoing electrolysis, after the oxide has already separated, will cause the solution of the latter. The current necessary for the deposition of metallic manganese, under the conditions mentioned above, should be feeble. The metallic deposit is inclined to rapidly oxidize, and whether manganese can be successfully determined in a quanitative way after this manner will depend very much upon whether we can prevent its oxidation during the drying process.

Nickel, cobalt, iron and several other metals separate very rapidly from cold sulphocyanide solutions under the influence of a weak current.

CHEMICAL LABORATORY, UNIV. OF PA.,
PHILADELPHIA, June 18, 1889.

ON THE CONSTITUTION OF LAPACHIC ACID AND ITS DERIVATIVES.

BY SAMUEL C. HOOKER AND WM. H. GREENE.

[*Read at the Meeting of the Chemical Section, held Tuesday, May 21, 1889.*]

In 1857, Arnoudon* described, under the name taiguic acid, a yellow coloring matter existing in the Taigu wood of Paraguay; nine years later, Stein † described as greenhartin a similar matter which he had extracted from the greenheart of Surinam. In 1879, Paterno ‡ proved the identity of these substances with the lapachic acid obtained by Siewert from the Lapacho tree of South America. Finally, we have recently found the same substance in a South African wood, the Bethabarra.§

Paterno, in an admirable research published in the

* *Comptes rendus*, **41**, *1,152*.

† *Jour. fur prak. Chemie*, **99**.

‡ *Gaz. Chim. Ital.*, **9**, 506.

§ *American Chem. Journal*, **11**, 267.

|| *Gaz. Chim. Ital.*, **12**, 337–392.

Gazzetta, 1882, has assigned to lapachic acid, with a very great degree of probability, the following constitutional formula:

$$C_{10}H_4 \begin{cases} O_2 \\ CH = CH - C_3H_7 \\ OH \end{cases}$$

Oxy-amylene-naphthaquinone.

The results from which this formula are mainly deduced are the following:

Lapachic acid gives a series of stable salts, but all experiments failed to reveal the true acid group, COOH.

On distillation with zinc dust, naphthalene and isobutylene were obtained.

On oxidation with nitric acid, phthalic acid was formed.

By reducing agents, a hydrolapachic acid was obtained, which rapidly absorbed oxygen, becoming reconverted into lapachic acid.

A monacetyl derivative was obtained.

Hydriodic acid and phosphorus gave a liquid hydrocarbon, which was taken to be amyl-naphthalene.

In the course of the study of this acid, Paterno prepared several compounds, which he was only able to explain satisfactorily by the assumption that two molecules of the acid had taken part in the formation of each of their molecules.

By the action of concentrated sulphuric acid on lapachic acid, a compound crystallizing in beautiful red needles is formed, which has precisely the same percentage composition as lapachic acid. This compound, which is known as lapachone, was assigned the following formula, by Paterno:

$$OH.C_{10}H_4(C_5H_9) \left\langle \begin{matrix} O.O \\ O.O \end{matrix} \right\rangle C_{10}H_4(C_5H_9).OH.$$

Lapachone is insoluble in alkaline carbonates; it is soluble in caustic alkalies only after boiling for some time. According to Paterno it separates from the alkaline solution on cooling and is almost completely precipitated unchanged on the addition of acids.

While recently engaged on the study of the coloring matter of Bethabarra wood, subsequently proved by us to be lapachic acid, we obtained an orange-red quinone-like substance. In the course of our experiments with this compound we observed a number of reactions which, when we had afterwards identified the compound as lapachone, did not agree with Paterno's view of its constitution.

We found that lapachone shows many of the characteristics of a chinone. It gives a white crystalline compound with acid sodic sulphite, which is reconverted by acids and alkalies into the original substance. It forms compounds with hydroxylamine and ammonia with great readiness, and gives the quinone color reaction of Bamberger.

These reactions are obviously not reconcilable with the formula given above and point to the probability that lapachone is $C_{15}H_{14}O_3$ and not $C_{30}H_{28}O_6$.

A determination of the molecular weight of lapachone, by Raoult's method, gave figures confirming this supposition, thus proving that only one molecule of lapachic acid is concerned in its formation, a result borne out by other facts.

Calculated for Paterno's formula $C_{30}H_{28}O_6$	*Calculated for* $C_{15}H_{14}O_3$	*Found.*
484	242	255

It remains, therefore, to explain how a substance having such strong acid tendencies as lapachic acid, dissolving with ease in alkaline carbonates, can be converted into an indifferent compound like lapachone, and yet retain the same percentage composition.

Although Paterno's formula of lapachic acid cannot be considered in any way proved, it lends itself well to the explanation of the formation of lapachone, and in this way considerable indirect proof is furnished of the probable correctness of Paterno's views in regard to lapachic acid.

It seems lawful to assume, that under the influence of strong mineral acids (concentrated nitric acid in the cold acts similarly to concentrated sulphuric acid as shown by Paterno) lapachic acid takes up a molecule of water,

giving rise to an intermediate compound, which is at once decomposed by the acid, again splitting off water, but in a different direction. This is shown in the following equation:

$$C_{10}H_4\begin{cases}O_2\\CH=CH.C_3H_7+H_2O\\OH\end{cases}$$

Lapachic acid.

$$=C_{10}H_4\begin{cases}O_2\\CH_2-CH(OH).C_3H_7\\OH\end{cases}$$

Oxy-hydro-lapachic acid.

$$=C_{10}H_4\begin{cases}O_2\\CH_2\\O\end{cases}\!\!>CH.C_3H_7+H_2O$$

Lapachone.

The fact that phthalic acid is produced by the oxidation of lapachic acid, would appear to furnish proof that all the side groups are situated in the same benzene nucleus, and consequently whether lapachic acid be a derivative of α- or β-napthaquinone the (OH) group must be in the ortho position to the amylene chain: this favors the probability of the occurrence of the above condensation.*

This view of the constitution of lapachone, *i.e.*, regarding it as a derivative of naphthofurfuran, agrees very thoroughly with all its properties and reactions so far observed. It has, moreover, received direct confirmation from the result of an experiment, which was made to obtain, if possible, corroboration of our views.

Paterno states, as already mentioned, that lapachone is insoluble in caustic alkalies in the cold, but dissolves on heating, and is, in part, deposited from the filtered solution unchanged as it cools.

This observation, seemed at variance with our idea of the constitution of lapachone, and we consequently carefully repeated Paterno's experiment. The insolubility of lapachone in alkaline carbonates and caustic alkalies in

* It is, of course, possible, though scarcely probable, that lapachic acid is derived from β β-naphthaquinone, in which case the relative positions of the amylene chain and the hydroxyl group would be the para.

the cold is readily explained by the constitution we have assigned to it, and its solubility on boiling is best accounted for by the supposition that the furfuran ring is split by the action of potash, that one molecule of water is taken up with the formation of a salt of the compound:

$$C_{10}H_4 \left\{ \begin{array}{l} O_2 \\ CH_2,CH(OH).C_3H_7 \\ OH \end{array} \right.$$

Oxy-hydro-lapachic acid,

which we had previously supposed to exist as an intermediate product in the formation of lapachone. This explanation proved quite satisfactory, for on neutralizing with acetic acid, a red oil was obtained which, in the course of an hour or so, solidified to a yellow crystalline mass.

Analysis proved it to have the expected composition. The tendency of the new substance to pass into lapachone under the influence of dilute mineral acids is very great, and hence if dilute HCl acid be used for the precipitation, either a mixture of lapachone and the new compound, or lapachone only is obtained.

We have not yet succeeded in preparing the potassium salt of the new substance in a crystalline form, but as its barium salt, which crystallizes very readily in bright orange needles, closely resembles lapachone, it is not improbable that the potassium salt may have a similar appearance, which would account for Paterno's supposition that the crystals deposited on cooling and before the addition of hydrochloric acid were crystals of lapachone. It is right to add that the fusing point of these crystals was found by Paterno to be almost identical with that of lapachone.

The salts of the new compound as might be expected dissolve to the same intense red color as those of lapachic acid. It melts at 125°, and is very readily soluble in most ordinary solvents. It may be obtained in comparatively large crystals, by spontaneous evaporation of its solution in alcohol or acetic acid.

By the action of bromine on lapachic acid in acetic acid solution, Paterno obtained a compound which he regarded

as monobrom-lapachic acid and to which he assigned the formula

$$C_{10}H_4\begin{cases}O_2\\ \ddot{C}H=CH.C_3H_7\\ OBr\end{cases}$$

Considering the properties of this compound and the probable constitution of lapachic acid, its formation would seem to be better explained by the supposition that an addition product is first formed, and that this by splitting off hydrobromic acid, gives rise to the formation not of brom-lapachic acid but of brom-lapachone, thus :—

$$C_{10}H_4\begin{cases}O_2\\ \ddot{C}H=CH.C_3H_7+Br_2\\ OH\end{cases}$$

$$=C_{10}H_4\begin{cases}O_2\\ \ddot{C}HBr-CHBr(C_3H_7)\\ OH\end{cases}$$

$$=C_{10}H_4\begin{cases}O_2\\ \ddot{C}HBr\\ O\end{cases}\!\!\!\!\!\!>CH.C_3H_7$$

We are at present endeavoring to prove the truth of this supposition and have already observed some important facts tending to show the correctness of our views.

The formation of several of the other compounds obtained by Paterno, would appear to be better explained in a similar manner to the foregoing than by the formulæ he has assigned to them. We prefer, however, to leave the discussion of these until our work has progressed further. In the meantime, we wish to say that, although we are hopeful further experiments will justify our present conclusions, we do not regard them as of necessity final and have only been induced to make this preliminary communication to ensure to ourselves the undisturbed continuation of the work, which, owing to many causes, can not, unfortunately, proceed with as great rapidity as we could desire.

ON KOBELLITE FROM OURAY, COL., AND THE CHEMICAL COMPOSITION OF THIS SPECIES.

BY HARRY F. KELLER.

[*Read at the Meeting of the Chemical Section, May 21, 1889.*]

The sulphobismutites and sulfostibnites of the southwestern part of Colorado, have repeatedly formed the subject of mineralogical and chemical research. Genth, Koenig, Hillebrand, and others have proved the occurrence there of a number of species already known from other localities, and have also described several new compounds of this class under the names of schirmerite, alaskaite and beegerite.

In the following pages, I desire to give the description of a mineral, possessing the composition $2(Pb,Ag_2,Cu_2)S.(Bi,Sb)_2S_3$ and to show further that it is in all probability identical with the kobellite of Setterberg.

The material for this investigation was kindly supplied by my brother, Mr. Hermann A. Keller, of Pueblo, Col. It consisted of several beautiful specimens of an ore that had been taken from the Silver Bell mine at Ouray, Col., by Mr. Philip Decker.

I have not been able to obtain any further information concerning the occurrence of the mineral, but consider it highly probable that it is closely analogous to that of alaskaite described by Koenig.* Like this it is found associated with barite and chalcopyrite. *Physical properties*:—Massive; structure, finely granular, inclining to fibrous; lustre, silky metallic; color, bluish lead-gray; fracture, uneven; streak, iron-black. Apparent hardness, 2·5—3; sp. gr., 6·334.

Chemical deportment.—Upon heating, the mineral first decrepitates violently and then fuses. In the open tube, it gives off sulphurous acid and a sublimate of antimonious acid. Upon charcoal it yields a yellow incrustation, with a white non-volatile fringe and a metallic globule, which for

* *Amer. Philos. Soc.*, June, 1881.

the greater part is volatilized upon continued blowing. The residue gives the reactions of iron and copper in the salt of phosphorus bead, and a button of metallic silver on cupellation. A crimson coating is obtained with potassium iodide and sulphur on charcoal.

Hydrochloric acid decomposes the compound with evolution of hydrogen sulphide, especially upon heating; the gangue material and chalcopyrite are left undissolved, while the silver passes into solution, from which it can be precipitated as chloride by diluting with water.

Chlorine, as well as nitric acid, exerts a powerful action upon it.

As the quantitative separation and estimation of the constituents present some difficulties, I will briefly indicate the course of an analysis which was found to be best adapted to this end. A portion of the mineral was treated with nitric acid. When proper care is taken, the oxidation is completed in an hour's time. The excess of the acid was then removed upon the water bath and the residue boiled with a solution of pure carbonate of soda. This treatment was continued until all the sulphuric acid, excepting the small quantity in the barite of the gangue, had passed in solution. The undissolved oxides and carbonates of the metals were then filtered off. The filtrate showed a bluish color, and was found to contain small quantities of copper, antimony and bismuth. These were precipitated, by hydrogen sulphide, after acidifying with hydrochloric acid, and the sulphur then determined in the filtrate as barium sulphate. This was purified after ignition, by heating with hydrochloric acid, then dissolving it in concentrated sulphuric acid and reprecipitating it finally with water.

The separation of the metals was effected as follows: The mixture of the oxides, carbonates, etc., was treated with nitric and tartaric acids, whereby only the gangue material ($BaSO_4$) remained undissolved. After the small quantity of sulphides before mentioned had likewise been taken up in the solution, the silver was precipitated as chloride in the cold; potassium hydrate was then added to the filtrate in excess and hydrogen sulphide passed into it. The

precipitate, consisting of the sulphides of all the metals except antimony, was filtered off, and the antimony determined in the liquid according to Bunsen's method as pentasulphide. The conversion of the pentasulphide into tetroxide served as a check, but gave invariably a slightly lower percentage.

The metallic sulphides were again oxidized with nitric acid, the latter removed by evaporation with sulphuric acid and the remaining sulphates treated with dilute sulphuric acid (1 : 8) in the cold. In this manner the lead is separated from the other metals, but not completely, as the insoluble sulphate always retains small quantities of bismuth. It is therefore dissolved in warm potash solution, which leaves the oxide of bismuth with some lead, and these can then be separated readily by a renewed treatment with nitric and sulphuric acids.

In the solution containing the sulphates of copper, bismuth, iron and zinc, the two first mentioned were precipitated as sulphides with hydrogen sulphide, filtered off, converted into the nitrates and separated from each other with ammonia and ammonium carbonate. Zinc and iron were finally separated and determined by the usual methods.

In order to ascertain which of the metals enter into the composition of the mineral, one portion of the substance (Analysis II) was dissolved in hydrochloric acid and the residue remaining analyzed separately.

Although chlorine acts strongly upon the finely divided powder, I did not succeed in effecting a complete decomposition by its means. All the samples analyzed were taken from different pieces of the ore.

ANALYSES.

	I.	*II.*	*III.*	*IV.*	*V.*	*Mean.*
S	18·37	—	18·46	18·33	18·39	18·39
Bi	27·97	28·51	28·68	28·46	—	28·40
Sb	7·19	7·25	7·91	7·84	—	7·55
Pb	36·11	36·08	36·25	36·20	—	36·16
Ag	3·22	3·39	3·30	3·32	—	3·31
Cu	2·43	2·26	2·91	2·76	—	2·59
Fe	1·31	1·35	1·69	1·65	—	1·50
Zn	·50	·37	·41	·31	—	·39
$BaSO_4$, etc.	·43	·65	·21	·49	—	·45
	97·53		99·82	99·36		98·74

In No. II the portion insoluble in hydrochloric acid was found to contain (after the chloride of silver had been removed by ammonia):

Fe, 1·09. Cu, 1·12. Zn, ·24.

It seems therefore safe to assume* that the iron and an equivalent quantity of copper are present as chalcopyrite, and the zinc as sphalerite.

Now deducting these, plus the gangue and the loss, the percentage composition calculated from the mean results is as follows:

		Atomic ratio.			
S	= 17·76	·5550		=	2·600
Bi	= 30·61	·1457	·2134	=	1·000
Sb	= 8·13	·0677			
Pb	= 38·95	·1881	·2124	=	·995
Ag	= 3·58	·0166			
Cu	= ·97	·0077			
	100·00				

and the formula is therefore: $2(Pb,Ag_2.Cu_2)S.(BiSb)_2S_3$. Since the atomic ratio of antimony† to bismuth is 1 : 2 the mineral may be considered as composed of one mol. of jamesonite with two mols. of cosalite.

The recent text-books of mineralogy do not assign this formula to any mineral, nevertheless such a one has been known for a long time.

As kobellite, Setterberg‡ in 1839 first described a mineral from the cobalt mines of Hvena, in Sweden, the composition§ of which he found to be:

S	= (18·61)
Bi	= 28·37
Sb	= 9·38
Pb	= 40·74
Fe	= 2·02
Cu	= ·88
	100·00

* Chalcopyrite, when finely divided, is slightly acted upon by HCl.

† I have reason to believe that the antimony determinations I and II are a little too low.

‡ *Pogg. Ann.*, **55**, 536.

§ Recalculated with present atomic weights (Rammelsberg, *Mineralch.*, p. 100).

Deducting from this the copper with the equivalent quantities of iron and sulphur, the atomic ratios are as follows:

$$\begin{array}{lll} S = \cdot5506 & & = 2\cdot581 \\ \left.\begin{array}{l} Bi = \cdot1351 \\ Sb = \cdot0782 \end{array}\right\} & \cdot2133 & = 1\cdot000 \\ \left.\begin{array}{l} Pb = \cdot1966 \\ Fe = \cdot0221 \end{array}\right\} & \cdot2187 & = 1\cdot025 \end{array}$$

that is, they are identical with those calculated from my analyses.

Setterberg states distinctly that the iron of his mineral was dissolved in hydrochloric acid, and must therefore be considered as belonging to it; another slight difference in the composition of the minerals from the two localities is the replacement of about one-twelfth of the lead by silver in that from Ouray.

In 1862, Rammelsberg published an analysis of some material from the Hvena mine; he found:

$$\begin{array}{lr} S = & 18\cdot22 \\ Bi = & 18\cdot60 \\ Sb = & 9\cdot46 \\ As = & 2\cdot56 \\ Pb = & 44\cdot25 \\ Fe = & 3\cdot81 \\ Cu = & 1\cdot27 \\ Co = & \cdot68 \\ \hline & 98\cdot85 \end{array}$$

After deducting 5·61 per cent. of (FeCo)AsS and 3·67 per cent. of $CuFeS_2$, he arrives at the formula

$$Pb_3BiSbS_6.$$

In his *Mineralchemie* (p. 100), he gives an analysis of so-called kobellite from another locality (the name of which is not mentioned), and from this deduces the same formula.

He does not prove, however, that the analysis by Setterberg is incorrect, and it is more than likely that the material examined by him consisted of a mineral different from Setterberg's.

There are numerous instances of the occurrence of two different sulpho-salts of similar appearance in the same vein, and even upon the same piece.

The re-investigation of alaskaite by Koenig* was caused by it having been mistaken for cosalite from the same mine.

The specific gravity determinations also show a slight discrepancy; Setterberg found 6·29 — 6·32, while Rammelsberg's determination gave 6·145. That of the Ouray occurrence is 6·334.

In view of all these facts, I feel myself justified in retaining the name of kobellite for the mineral of the formula:

$$2(Pb,Ag_2,Cu_2,Fe)S.(Bi_{(2)},Sb_{(1)})S_3,$$

and would suggest that another name be given to that to which this name has hitherto been applied, namely,

$$Pb_3SbBiS_6.$$

In concluding, I desire to propose the name of lillianite for a mineral from the Lillian mine in Leadville, Col., described several years ago jointly by my brother and myself as a variety of kobellite. It possesses the composition $3(PbAg_2)S.Bi_2S_3$, and represents the bismuth mineral corresponding to boulangerite.

II.—ANALYSIS OF MEGABASITE FROM BONITA MOUNTAIN, NEAR SILVERTON, COL.

More than three years ago I received from Colorado, among other specimens, one which was labelled "gœthite." Some qualitative tests that were then performed upon it proved that it consists essentially of tungstic acid and manganous oxide. The occurrence has become quite well known since, but, as far as I am aware, no quantitative analysis of the material has been published. I may therefore be permitted to put the following on record:

Sp. Gr. = 6·780

WO_3	=	74·24
MnO	=	21·09
FeO	=	2·06
CuO	=	·11
MgO	=	trace
SiO_2	=	2·13
		99·63

CHEMICAL LABORATORY, UNIV. OF PA.,
PHILADELPHIA, May 21, 1889.

* *Proc. Amer. Philos. Soc.*, 1885, 211.

THE ELECTROLYTIC SEPARATION OF CADMIUM FROM ZINC.

BY EDGAR F. SMITH AND LEE K. FRANKEL.

[*Read at the Meeting of the Chemical Section, May 21, 1889.*]

The separation of these metals has been effected by Yver (*Bull. Soc. Chim. de Paris*, **34**, 18), who employed the acetates for this purpose.

Eliasberg (*Zeitschrift für Analyt. Chemie*, **24**, 548) and Smith and Knerr (*Am. Chem. Journal*, **8**, 210) confirmed this observation, at the same time emphasizing the fact that the current should be carefully regulated, otherwise unsatisfactory results would be obtained. A solution containing cadmium and zinc as tartrates, together with free tartaric acid, will also yield all its cadmium to a current generating 0·4—0·5 cc. oxy-hydrogen gas per minute (*Am. Chem. Journal*, **8**, 210). We have no record of other salts of these metals having been used for their electrolytic separation, and therefore have taken occasion to learn what the result might be with solutions of the double cyanides, such as we employed in separating mercury and copper (JOURNAL FRANKLIN INSTITUTE, **127**, 469, and *Am. Chem. Journal*, **11**, 264).

Beilstein and Jawein (*Ber. d. d. chem. Gesellschaft*, **12**, 446, 762) have shown that both cadmium and zinc can be completely precipitated from a cyanide solution, but have not given the current strength employed by them in their experiments, nor did they attempt the separation of these metals from each other.

As our experience with mercury and copper clearly indicates, it is frequently possible, by close attention to the current, to effect electrolytic separations, which ordinarily seem impossible. With this fact clearly before us, our first work with the metals now under consideration was to ascertain how feeble a current would suffice for the complete deposition of each metal, when alone in a cyanide solution, in the presence of an excess of an alkaline cyanide. We very soon discovered that the cadmium separated readily

and with a much weaker current than was necessary for the deposition of the zinc. The latter will, however, separate from a cyanide solution, even under the influence of a feeble current, but not until the excess of cyanide has been completely decomposed. With the quantity of cyanide used by us, and with a current of the strength indicated below, this complete decomposition of the alkaline cyanide is not likely to occur in a shorter period than forty-eight hours. Hence, it follows, that as the quantity of cadmium used in our experiments is entirely precipitated in a little more than eighteen hours, the complete separation of cadmium from zinc is thoroughly feasible by this method.

All our experiments were conducted in the cold, and care was taken in each case to examine the deposited metal for zinc, and the residual solution for cadmium. The conditions under which our work was carried on and the results obtained are these:

Metallic Cadmium in Grammes.	Cadmium found.	Metallic Zinc present.	Difference in per cent. of Cadmium.	KCN in Grammes.	Total Dilution.	Current in cc of O–H Gas.	Time.
			Per Cent.				
·1817	·1813	. . .	— ·22	4·5 grammes in each separation.	200 cc.	0·3 cc. in each experiment.	18–23 hours.
	·1818	. . .	+ ·05				
	·1815	. . .	— ·11				
	·1822	. . .	+ ·22				
	·1812	·2000	— ·27				
	·1818	·2000	+ ·05				
	·1828	·2000	+ ·60				
·2426	·2422	. . .	— ·16				
	·2432	. . .	+ ·24				
	·2426	. . .	. . .				
	·2420	·2000	— ·24				
	·2435	·2000	+ ·30				
	·2429	·2000	+ ·12				
	·2426	·2000	. . .				
	·2433	·2000	+ ·28				
	·2434	·2000	+ ·32				

The cadmium deposit was light gray in color and crystalline in structure. It was washed with hot water and dried upon a warm iron plate.

CHEMICAL LABORATORY OF THE UNIV. OF PA.,
PHILADELPHIA, May 21, 1839.

DERIVATIVES OBTAINED FROM MONOCHLOR-DINITROPHENOL AND BASES OF THE AROMATIC SERIES.

BY EDGAR F. SMITH.

[*Read at the Stated Meeting of the Chemical Section, May 21, 1889.*]

It is well known that picric acid combines readily with bases and the higher hydrocarbons of the aromatic series to form well crystallized and stable compounds. It has, however, not been observed that phenols, containing less than three nitro-groups, together with other negative groups or elements, possessed this acidic property of picric acid. Several years ago (*Am. Chem. Journal*, **1,** 180) I discovered that when monochlordinitrophenol (1 : 2 : 4 : 6) and aniline were brought together there resulted a rather stable derivative, which did not decompose in aqueous solution until after prolonged boiling. Recently I have obtained derivatives with this same chlordinitrophenol and the bases and hydrocarbon mentioned below.

The phenol itself forms yellow-colored needles, melting at 80° C. Its *α-naphthylamine* derivative consists of brownish-yellow crystalline tufts, composed of velvety needles, melting at 131° C., and solidifying at 110° C. It was obtained by dissolving equal quantities of the phenol and *α*-naphthylamine in hot alcohol; on cooling, the new compound separated quite rapidly. It dissolves in warm water. The *o-toluidine* derivative, obtained by heating together equivalent quantities of the phenol and toluidine, consists of golden yellow plates, soluble in hot alcohol. It melts at 140° C., and solidifies at 115° C.

The *p-toluidine* compound separated from its alcoholic solution in reddish-yellow needles, was quite soluble in water, and melted at 157° C. With *urea* the phenol does combine, but the union is evidently unstable, since by exposure to the air a gradual change in color was perceptible. The *carbazol* compound consists of intensely red colored needles, melting at 121° C. It dissolves quite readily in alcohol.

With *p-nitraniline* long needles were obtained. Their color resembled that of chromic acid. It was rather difficult to obtain them pure. The *anthracene* derivative forms plates with an intense red color. The union is not stable, and exposure to the air causes a gradual decomposition. The *morphine* compound is made up of bundles of needles, having a deep vermilion color. It dissolves in alcohol, and melts at 97° C. The combination with *propylamine* is a yellow, crystalline solid; that with *strychnine* consists of yellow nodular crystals, melting at 212° C.

The determination of the carbon and hydrogen in the aniline compound, and that of the nitrogen in the *α*-napthylamine and *o*-toluidine derivatives, show that all the products described above are very probably combinations of a molecule of the chlordinitrophenol, with a like amount of the basic body.

I have further observed that dichlormononitrophenol, obtained in the nitration of dichlorsalicylic acid (*Am. Chem. Journal*, **8**, 98), does not unite with aniline, so that it would seem that the acidic character of the phenol reached its limit with the dinitro-product; and that union with bases such as those given above, is not possible when but one NO_2 group is present.

The facts here communicated are to be regarded as preliminary to an investigation now going on, but which must shortly be suspended for some months.

CHEMICAL LABORATORY OF UNIV. OF PA.,
PHILADELPHIA, May 21, 1889.

CORRESPONDENCE.

WASHINGTON, D. C., June 20, 1889.

To the Committee on Publications.

GENTLEMEN:—The following graphic construction for determining the electrical resistance of divided circuits has, I believe, never been published. It is probably of no practical importance, but may however be of sufficient interest to be placed on record.

Let it be required to determine the electrical resistance between the points *M* and *N* of *Fig. 1*, connected by two conductors; one of three ohms and the other of six ohms.

Through two arbitrary points, *A* and *B*, of an indefinite straight line, draw the two ordinates *A6*, *B3* proportional to the given resistances. Through *O*, the intersection of the diagonals *A3*, *B6*, draw the ordinate *OK*, the length of which gives the required resistance, two ohms.

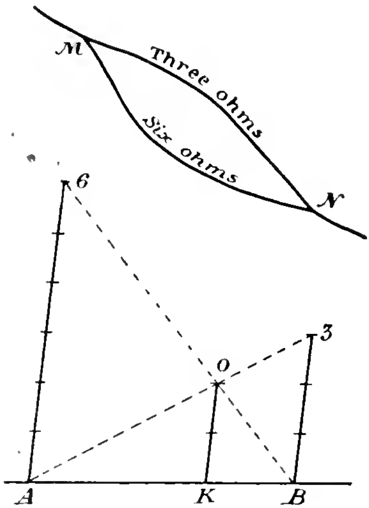


FIG. 1.

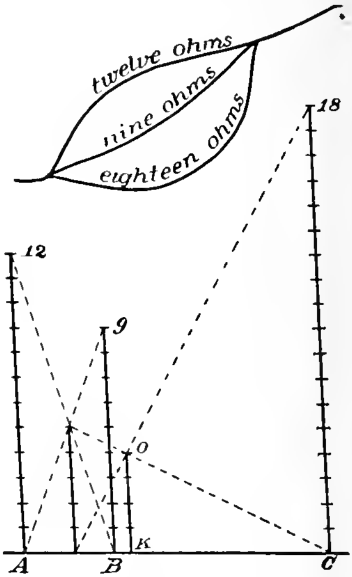


FIG. 2.

Fig. 2 shows the same construction applied to a divided circuit of three branches of twelve ohms, nine ohms and eighteen ohms.

The branches twelve and nine have a combined resistance of five ohms, which with the parallel branch of eighteen ohms give four ohms.

The same construction may evidently be applied to any number of branches.

J. B.

BOOK NOTICES.

THE CHRONICLE FIRE TABLES FOR 1889. A record of the fire losses in the United States by risks, States and causes during 1888, with exhibits of the monthly, annual and aggregate fire losses in the United States during fourteen years (1875–1888), and much other interesting and valuable information for fire underwriters. The Chronicle Company, limited, New York. Price, $5.

This excellent statistical work, now in the fifth year of its present form (though previously a smaller volume was published, with data not so full, dating back to 1875), is becoming annually more and more important; there is not a similar work in the world which can equal it. The volume is of royal octavo, and filled with the fullest data pertaining to the subjects set forth in its title. There is a general review of the fires occurring in the United

States during 1888, with discussions and comparisons of their amounts of losses and causes. Next comes the principal tabular statement, occupying eighteen pages, wherein, following nearly the classification of the Tenth Census of the United States, the number of fires during 1888 in each classification is given, together with the property and insurance loss, and causes of the fires reported.

One valuable addition hereto is a list of fires and their losses happening in warehouses of different descriptions, comprising thirty-nine kinds of storage. The modes used to insure accuracy are known to us, and are about as perfect as human ingenuity can devise. Absolute correctness in such data is not possible, but here is a close approximation. The fires and their losses are afterward given in same classes by States and Territories, occupying eighty-six pages. Another table exhibits the fires by causes, with number, losses on original risks, insurance thereon, losses on exposures and their insurances, besides the character of risks where fire originated. Nothing could be better devised than this compendium, in connection with the other data given, to facilitate study of this subject.

There are extensive tabulations, showing the number and kinds of risks burned in the United States for fourteen years (1875–1888), the monthly losses by fire in States and Territories during 1888 and for the thirteen previous years; also, an appendix, giving the number of lives lost by fires during the past year, reports of tornadoes accompanied by fires, besides much other statistical information respecting fires due to special causes, such as electricity, petroleum, etc. There are five charts, showing by various degrees of shading the distribution of incendiarism in the United States, and several diagrams exhibiting the monthly curves of incendiary fires and their failures during the year. An attractive diagram in blue, at the front, shows, by different divisions and shadings, where and to what degree fires due to defective flues—one chief cause—prevailed. We think that all business men, insurance companies, attorneys, students and all public institutions and libraries should possess these valuable fire tables and the four volumes which precede them. To the student of social economy they are simply invaluable. X.

CURVE PICTURES OF LONDON FOR THE SOCIAL REFORMER. By Alex. B. MacDowall, M.A. London: Sampson Low & Co. 12mo. 1888.

The object of this volume of fifty pages is to give graphic views by diagrams, each having a page of explanation, of important facts relating to London and phases of its life in different times and conditions. These diagrams show in various percentages, etc., the population of the city and its density, birth-, marriage- and death-rates, early marriages, deaths by disease (four diagrams), suicides, drunkenness, licensed houses, apprehensions, felonies and property, pauperism (four diagrams), education, illiteracy, prices of commodities and prices of meat. The increase or decrease of the subject treated is also clearly shown.

The population is compared with that of Scotland, Paris and New York; its vast increase has been from 958,863, in 1801, to 3,800,000, in 1881. The density of population per acre varies much, and is delineated by districts

and sub-districts. Marriage is shown to fluctuate with trade, and exhibits a general decline; early marriages, however, are increasing, thus tending to increase poverty. The violence of the principal diseases is shown at different times, and by number of deaths per 1,000 of population. The death ratio of the city has fallen with improved conditions of life. This enumeration will suffice to show the student of economic science, and others, that here is a considerable field for research. This condensed work holds information which could fill a volume five times its size. The book is well worthy of careful study. S. H. N.

NOTES AND COMMENTS.

MECHANICS.

Products of the Simonds Rolling Machine. By S. L. Wiegand. (Abstract of remarks made at the Stated Meeting, held Wednesday, June 19, 1889.)—At the meeting of the Institute, held one year ago, Mr. George F. Simonds, of Fitchburg, Mass., exhibited by a model and explained by diagrams, a newly-invented machine for rolling metals into forms which not only performed the work of the smith forge better than smiths had ever done it, but also produced many articles in metal completely finished without either cutting, filing or grinding them. (His paper was published in the Journal, July, 1888.)

This invention was referred to the Committee on Science and the Arts, and, after careful examination, was pronounced so important and useful that the Elliott Cresson Medal was awarded to him for it, and their report was published in full in the Journal for November, 1888.

Conspicuous among the products shown were very accurately formed, hardened and polished cast-steel balls for use in avoiding friction between the parts of machines.

Many persons observing them and their intended application, expressed doubt of their utility and durability.

The diagram (on the screen) shows them in several applications in which they have been tested severally with the best results, as to easy running of the machines and their apparently excellent durability.

Another slide shows the improved form of machine for making such balls in which the balls are used in all the high-speeded bearings.

Incidentally there occur in this machine two worm-wheels and endless screws, replacing a train of spur-wheels and pinions employed in the earlier machine, and which show a marked and most unexpected durability at high speed under great strain and indicate that under high velocities and with proper lubrication, such gearing moves with less friction, proportionally, than in slower moving machines—a fact of considerable interest to machine constructors, encouraging them to avoid long trains of reducing mechanism to convert the high velocities of electric motors into the slower speeds demanded by many operations in the arts.

A number of additional specimens are here shown, an inspection of which will tell more to the eye of a mechanic than anything that can be said.

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR JUNE, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, June 30, 1889.

TEMPERATURE.

The mean temperature for the month of June, 1889, was 66°·5, which is from two to three degrees below the average, and two degrees below the corresponding month of last year.

The means of the daily maxima and minima were 76°·4 and 57°·0, respectively.

Neither extreme high nor low temperatures were noted during the month.

The warmest period at most stations was on the 21st, and the coldest on the 2d, 7th and 24th. Frost occurred in some of the northern border counties on these dates.

The highest recorded temperatures were: Reading, 95°; Carlisle, 93°; Pottstown, 91° and York, 91°.

The lowest were Dyberry, 33°; Honesdale, 35°, and State College, 37°.

BAROMETER.

The mean pressure was 0·06 above the normal. The greatest pressure was on the 24th, and the least on the 5th. The extreme range was about 0·75.

PRECIPITATION.

The average rainfall for June, 1889, was 5·43 inches, which is an excess of 1·63 inches.

The entire month was characterized by frequent and heavy rainfalls. The great and destructive rain-storm of the 30th and 31st of May continued to the morning of June 1st over a great extent of country. On the last-named date, over twenty stations report a fall of from one to three inches, making a total in inches for the three days' storm, as follows: Wellsboro, 9·80; McConnellsburg, 8·99; Grampian Hills, 8·60; Harrisburg, 7·78; Selins Grove, 7·53; Charlesville, 7·50; Huntingdon, 6·57; Coudersport, 6·33; Phillipsburg, 6·09; Smethport, 6·00; New Bloomfield, 6·14; Emporium, 5·97; Hollidaysburg, 5·80; Eagles Mere, 5·53; Altoona, 5·33; Girardville, 4·59; Somerset, 4·43; Myerstown, 3·37.

For the month of June, 1 station had rain on 21 days, 4 stations on 20 days, 1 station on 19 days, and 3 stations on 18 days. The average for the state was 15 days.

The following stations report the greatest total in inches: Wellsboro, 10·04; Myerstown, 8·66; Reading, 8·21; Girardville, 8·01; Scisholtzville, 7·91; Ottsville, 7·58; Smith's Corner, 7·54; Uniontown, 7·36; Quakertown, 7·31, and Harrisburg, 7·18.

The excessive rainfall, and the unusual number of rainy days, marks the month as exceptionally wet. With the exception of the 2d, 23d and 24th, rain fell on every day in some part of the state.

WIND AND WEATHER.

The prevailing winds were from the west and southwest, with no severe and general gales. A few frosts were reported, but no damage of any amount resulted from them. The month was excellent for the growth of all vegetation, and large crops were secured where harvesting was not interfered with by the excessive wet.

In some sections the damage to the hay crop was very great.

Average number.—Rainy days, 15; clear days, 5; fair days, 12; cloudy days, 13.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Charlesville, 4th, 11th, 14th, 16th, 21st, 28th; Reading, 4th, 5th, 9th, 11th, 15th, 17th, 21st, 29th, 30th; Hollidaysburg, 14th, 21st; Quakertown, 9th, 11th, 15th, 17th, 21st, 29th; Emporium, 21st, 30th; State College, 4th, 21st, 28th; Phillipsburg, 15th, 21st; West Chester, 5th, 10th, 15th, 17th, 21st; Coatesville, 5th, 10th, 15th, 17th, 21st, 30th; Rimersburg, 14th, 19th, 21st, 27th, 30th; Carlisle, 9th; Harrisburg, 17th; Swarthmore, 5th, 10th, 11th, 14th, 15th, 21st, 30th; Uniontown, 14th; Huntingdon, 4th, 11th, 15th, 17th, 28th; Indiana, 11th; New Castle, 4th, 17th, 27th; Myerstown, 5th, 9th, 11th, 15th, 17th, 21st; Smethport, 21st; Greenville, 17th, 30th; Pottstown, 4th, 15th; New Bloomfield, 4th, 9th, 15th, 21st; Philadelphia, 4th,

Service for June, 1889.

Precipitation.	Number of Days.			Wind.			Observers.
				Prevailing Direction.			
Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
18	1	8	21	SW	SW	SW	Oscar D Stewart, Sgt. Sig. Corps.
15	5	12	13	W	SW	W	Rev. A. Thos. G. Apple.
16	11	7	12	NW	. . .	SW	C. M. Dechant, C.E.
17	. . .	. . .	. . .	. . .	. . .	. . .	Dr. Charles B. Dudley.
20	5	19	6	SW	W	W	Prof. J. A. Stewart.
16	7	7	16	SE	SW	NW	Charles Beecher.
11	4	18	8	W	W	W	J. C. Hilsman.
17	4	15	11	SW	SW	SW	J. L. Heacock.
12	4	16	10	E	W	W	T. B. Lloyd
15	3	13	14	W	W	W	Prof. Wm. Frear.
20	3	9	18	SW	SW	SW	Geo. H. Dunkle.
19	11	14	5	S	SW	SW	Jesse C. Green, D.D.S.
15	10	12	8	W	S	W	W. T. Gordon.
18	6	11	13	SE	SW	S	Rev. W. W. Deatrick, A.M.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	C. M. Thomas, B.S.
17	3	10	17	W	SW	SW	Nathan Moore.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. John A. Robb.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Robert M. Graham.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	R. B. Derickson.
17	5	14	11	S	S	S	J. E. Pague.
20	5	15	10	E	E	E	Frank Ridgway, Sgt. Sig. Corps.
10	3	8	19	SW	SW	SW	Prof. Susan J. Cunningham.
8	3	9	18	SE	SE	SE	Peter Wood, Sgt Sig. Corps.
21	7	19	4	W	W	W	Wm Hunt.
15	8	13	9	W	W	W	Thomas F. Sloan.
16	5	10	15	W	W	W	Prof. W. J. Swigart.
13	4	8	18	SW	W	SW	Prof. Albert E Maltby.
9	3	4	23	SE	SE	SE	Wm. T. Butz.
13	7	18	5	W	W	W	Wm. H. Kline.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Geo. W. Bowman, A.M., Ph.D.
11	4	16	10	. . .	. . .	. . .	H. D. Miller, M.D.
13	4	14	12	S	S	S	Armstrong & Brownell.
10	5	5	20	SW	SW	SW	Prof S. H. Miller.
10	13	11	6	W	W	W	Charles Moore, D.D.S.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Lerch & Rice.
13	5	12	13	S	SE	SE	Frank Mortimer.
13	2	13	15	SW	SW	SW	Luther M. Dey, Sgt. Sig Corps.
11	7	6	17	W	W	W	C. L. Peck.
15	10	12	8	W	W	W	E. C Wagner.
14	3	15	12	SW	SE	SE	J. M. Boyer,
14	6	11	13	SW	SW	SW	W. M. Schrock.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	E. S. Chase.
20	4	12	14	S	SW	SW	H. D. Deming.
18	4	9	17	SW	SW	SW	Wm. Loveland.
11	5	14	11	W	W	W	Theodore Day.
12	. . .	. . .	. . .	. . .	. . .	. . .	John Torrey.
13	15	8	7	SW	SW	SW	Mrs. L. H. Grenewald.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for June, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Precipitation. Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction. 7 A. M.	Wind. Prevailing Direction. 2 P. M.	Wind. Prevailing Direction. 9 P. M.	Observers.
Allegheny,[1]	Pittsburgh,	847	30.004	30.420	29.720	67.3	87.0	21, 30	46.0	2	76.1	60.4	15.7	24.0	7	7.0	1	70.4	56.8	4.93	18	1	8	21	SW	SW	SW	Oscar D. Stewart, Sgt. Sig. Corps.
Bedford,	Charlesville,	1,300	...	...	...	64.8	86.5	21	43.0	24	76.1	58.7	17.4	29.5	24	9.0	11	81.8	59.3	4.26	15	5	12	13	W	SW	W	Rev. A. Thos. G. Apple.
Berks,[1]	Reading,	304	30.043	30.399	29.721	67.8	95.0	20	44.0	7	80.9	58.9	22.0	34.0	21	5.0	11	85.1	62.6	8.21	16	11	7	12	NW	...	SW	C. M. Dechant, C.E.
Blair,[2]	Altoona,	1,181	...	...	...	69.6	88.0	22	47.5	2	79.2	60.1	19.1	26.5	18	11.0	19	62.5	56.0	4.73	17	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947	...	...	...	66.0	90.0	21	40.0	2	78.0	53.0	25.0	43.0	8	10.0	12	83.0	62.0	2.71	20	5	19	6	SW	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718	30.010	30.466	29.659	69.0	87.5	21	39.0	7	76.7	55.0	21.7	38.0	7	6.1	12	82.2	60.0	4.86	16	7	7	16	SE	SW	NW	Charles Beecher.
Bucks,	Forks of Neshaminy,	...	...	...	...	66.5	82.0	21	54.0	7	...	...	...	...	...	...	...	...	...	4.49	11	4	18	8	W	W	W	J. C. Hilsman.
Bucks,	Quakertown,	536	30.030	30.450	29.570	67.2	87.5	21	40.0	7	79.0	56.1	23.9	35.7	7	14.7	5	86.5	63.7	7.31	17	4	15	11	SW	SW	SW	J. L. Heacock.
Cameron,	Emporium,	1,030	...	...	...	68.2	90.0	21	38.0	7	77.7	53.9	23.8	39.0	21	2.0	5	74.8	60.0	4.63	12	4	16	10	E	W	W	T. B. Lloyd
Centre,	State College—Agricultural Experiment Station,	1,191	29.977	30.385	29.629	64.9	85.0	21	37.0	2	73.9	52.4	21.5	31.0	21	14.0	5	83.2	59.9	5.37	15	3	13	14	W	W	W	Prof. Wm. Frear.
Centre,	Phillipsburg,	1,350	...	...	...	62.4	88.0	29, 30	38.0	2	75.3	53.1	22.2	35.0	24	11.0	5	...	...	5.84	20	3	9	18	SW	SW	SW	Geo. H. Dunkle.
Chester,	West Chester,	455	30.024	30.446	29.643	68.9	86.5	21	48.0	7	77.5	61.2	16.3	26.0	7	10.0	5	75.0	60.5	5.38	19	11	14	5	S	SW	SW	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	68.7	89.5	20, 21, 28	42.0	7	80.1	58.6	21.5	35.0	7	12.0	30	...	...	5.99	15	10	12	8	W	S	W	W. T. Gordon.
Clarion,	Rimersburg,	1,500	...	...	...	68.2	86.0	29, 30	47.0	1	74.1	61.7	12.4	25.0	21	2.0	5	...	...	...	18	6	11	13	SE	SW	S	Rev. W. W. Deatrick, A.M.
Clarion,	Clarion—State Normal School,	1,530	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	...	...	...	64.5	88.0	21	48.0	1, 2	75.0	60.0	15.0	28.0	24	6.0	5	...	...	3.71	17	3	10	17	W	SW	SW	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. John A. Robb.
Columbia,	Catawissa,	491	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Robert M. Graham.
Crawford,	Meadville—Allegheny College,	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. B. Derickson.
Cumberland,	Carlisle,	480	...	...	...	69.1	93.0	21	50.0	2	78.5	63.1	15.4	31.0	20	2.0	12	84.4	64.0	4.59	17	5	14	11	S	S	S	J. E. Pague.
Dauphin,[1]	Harrisburg,	361	30.054	30.480	29.690	67.4	87.0	21	50.0	2	76.8	60.2	16.6	26.0	13	3.0	12	76.6	59.4	7.18	20	5	15	10	E	E	E	Frank Ridgway, Sgt. Sig. Corps.
Delaware,	Swarthmore—Swarthmore College,	190	30.016	30.436	29.655	69.3	87.2	20	46.2	5	78.1	59.8	18.3	32.5	8	10.9	10	78.5	63.0	5.48	10	3	8	19	SW	SW	SW	Prof. Susan J. Cunningham.
Erie,[1]	Erie,	681	30.007	30.460	29.680	64.0	82.9	9	45.0	1	70.0	57.0	13.0	22.0	9	4.0	22	76.0	56.0	6.02	8	3	9	18	SE	SE	SE	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	30.022	30.332	29.740	67.8	87.0	21	44.0	2	76.2	58.1	18.1	30.0	24	6.0	1	79.0	61.5	7.36	21	7	19	4	W	W	W	Wm. Hunt.
Fulton,	McConnellsburg,	875	...	...	...	66.2	87.0	21	40.0	7	77.6	57.2	19.4	36.0	7	5.0	19	78.1	58.2	5.17	15	8	13	9	W	W	W	Thomas F. Sloan.
Huntingdon,	Huntingdon—The Normal College,	650	...	...	...	65.2	89.0	29	38.0	2	75.1	54.6	20.5	35.0	7	8.0	12	...	...	5.60	16	5	10	15	W	W	W	Prof. W. J. Swigart.
Indiana,	Indiana—State Normal School,	1,350	...	...	...	67.9	87.0	21	44.0	23	76.5	58.2	18.3	29.0	21	10.0	26	80.2	61.0	3.39	13	4	8	18	SW	W	SW	Prof. Albert E. Maltby.
Lawrence,	New Castle,	932	...	...	...	68.7	87.0	29	38.0	6	77.1	53.3	23.8	35.0	7	15.0	11	...	...	6.50	9	3	4	23	SE	SE	SE	Wm. T. Butz.
Lebanon,	Myerstown,	474	30.014	30.722	29.654	66.3	87.4	20	43.0	7	78.9	58.4	20.5	34.0	7	11.2	12	90.0	63.8	8.66	13	7	18	5	W	W	W	Wm. H. Kline.
Lebanon,	Annville—Lebanon Valley College,	339	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Geo. W. Bowman, A.M., Ph.D.
Luzerne,	Drifton—Drifton Hospital,	1,655	...	...	...	63.6	86.0	21	44.0	8	75.9	55.0	20.9	34.0	8	10.0	5	...	...	4.99	11	4	16	10	...	...	...	H. D. Miller, M.D.
McKean,	Smethport,	1,500	...	...	...	67.4	88.0	30	38.0	25	75.8	52.0	23.8	37.0	25	6.0	11	80.0	61.0	5.93	13	4	14	12	S	S	S	Armstrong & Brownell.
Mercer,[1]	Greenville—Thiel College,	1,000	29.954	30.390	29.642	63.5	87.0	30	41.5	1	73.7	54.8	18.9	32.0	24	9.9	22	...	...	3.51	10	5	5	20	SW	SW	SW	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	...	...	...	71.3	91.0	21	53.0	24	78.9	64.0	14.9	28.0	21	3.0	5	76.5	62.0	6.20	10	13	11	6	W	W	W	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	...	...	...	70.2	88.0	21	46.0	7	79.1	60.0	19.1	35.0	8	7.0	25	73.0	61.0	5.28	...	...	...	...	...	...	...	Lerch & Rice.
Perry,	New Bloomfield,	400	...	...	...	66.2	90.0	20	40.0	19	74.2	54.2	20.0	38.0	9	12.0	12	...	...	6.25	13	5	12	13	S	SE	SE	Frank Mortimer.
Philadelphia,[1]	Philadelphia,	117	30.050	30.460	29.680	69.8	88.0	20, 21	54.0	6, 7	79.4	63.3	16.1	22.0	20	10.0	12	74.0	60.8	3.39	13	2	13	15	SW	SW	SW	Luther M. Dey, Sgt. Sig. Corps.
Potter,	Coudersport,	1,670	...	...	...	65.2	86.0	20, 21	35.0	7	75.4	48.8	26.6	41.0	20	11.0	1	80.4	60.4	4.80	11	7	6	17	W	W	W	C. L. Peck.
Schuylkill,	Girardville,	1,000	30.052	30.457	29.716	66.0	85.0	21	47.0	7	75.7	56.0	19.7	33.0	8	11.0	12	...	...	8.01	15	10	12	8	W	W	W	E. C. Wagner.
Snyder,	Selins Grove,	445	...	...	...	68.2	80.0	16, 30	55.0	6, 7	75.7	63.0	12.7	20.0	24	6.0	5	...	...	5.10	14	3	15	12	SW	SE	SE	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	60.4	83.0	21	41.0	1, 23	73.6	54.4	19.2	30.0	24	7.0	22	...	...	3.87	14	6	11	13	SW	SW	SW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. S. Chase.
Tioga,	Wellsboro,	1,327	29.973	30.463	29.608	63.3	86.0	10, 29	42.0	24	74.2	55.2	19.0	9.5	24	3.0	5	...	...	10.04	20	4	12	14	S	SW	SW	H. D. Deming.
Warren,	Columbus,	1,410	30.121	30.576	29.802	63.2	90.0	30	38.0	6, 7, 24	73.8	52.6	21.2	40.0	24	8.0	11	80.2	55.6	5.12	18	4	9	17	SW	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	63.0	85.0	30	33.0	7	74.0	52.0	22.0	40.0	7	11.0	12	...	...	4.24	11	5	14	11	W	W	W	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	63.7	82.0	10, 29	35.0	7	73.7	53.7	20.0	36.0	7	9.0	1	...	...	3.13	12	...	...	...	...	...	...	John Torrey.
York,[1]	York,	385	30.036	30.489	29.745	66.5	91.0	21	49.0	1, 2, 24	79.8	59.6	20.2	33.0	7	5.0	25	72.2	59.4	5.13	13	15	8	7	SW	SW	SW	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

Erie.	New Castle.	Greenville.	Columbus.	Pittsburgh.	Uniontown.	Clarion.	Quakertown.	Swarthmore.	Philadelphia.	Scisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Nesham'y	Germantown.	Point Pleasant.	Bethlehem.
·14	1·05	. .	·34	. .	·04	.	·95	·58	·46	1·93	·98	·19	1.02	·68	1·67	·70	. .	·44	1.00
. .	. .	. .	. .	. .	. .	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·04	. .	. .	. .	·04	·21	.	·03	. .	·02	. .	. .	·15	·04	. .	. .	. .	·04	. .	. .
·04	1·50	. .	·05	·44	·06	.	·04	·02	. .	. .	·09	·13	·06	. .	. .	·03	. .	·01	.22
.03	. .	. .	·12	·08	·21	.	·16	·34	·20	·33	·30	. .	·10	·24	. .	·14	·09	·01	. .
·02		. .	·08	.	. .	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·08	·30	. .	·10	. .	·02	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·90	. .	. .	·97	·19	·43	.	·04	. .	. .	·48	·05	·05	. .	. .	. .	·01	. .	. .	. .
·24	. .	. .	·12	·06	. .	.	·11	. .	. .	·63	. .	·17	·03	·90	. .	·55	. .	·05	·04
·02	. .	. .	. .	·02	·23	.	. .	. .	. .	. .	. .	. .	. .	. .	·11	. .	. .	. .	. .
. .	·35	·17	.15	·90	·10	.	·44	. .	. .	·72	·32	·84	·31	·26	·22	·20	. .	1·10	·97
. .	. .	. .	. .	·08	·21	.	·35	·60	·43	·10	·33	·12	1 02	·99	·34	. .	1·16	·05	·68
. .	. .	. .	. .	. .	·01	.	·02	·12	. .	. .	·15	. .	. .	. .	. .	·70	. .	. .	
·04	. .	·32	·02	·08	·29	.	. .	·68	·04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·32	·50	·23	·51	1·73	·51	.	1·63	·72	·54	·78	1·75	1·18	·76	·56	·92	. .	·54	·50	.71
·99	. .	·62	·50	·04	·27	.	·41	. .	. .	. .	·77	. .	. .	. .	. .	·16	·04	·25	. .
2·15	·57	1·19	·92	·12	1.14	.	1·05	. .	·05	·51	. .	·40	·80	·53	. .	. .	.14	·84	·04
. .	. .	. .	. .	. .	. .	.	·07	. .	·01		.	.	. .	. .	. .	. .	. .	.	. .
·10	. .	·04	·11	·31	·26	.	. .	.	.	. .	.	.	. .	. .	·10	. .		.	. .
·10	. .	. .	·25	. .	·27	.	. .	.	. .	. .	. .	. .	. .	. .	. .	.	. .	. .	. .
·14	·78	·20	·13	·20	·78	.	·04	. .	·01	·75	·22	·22	.21	·11	. .	·10	. .	·15	44
. .	. .	. .	. .	. .	. .	.	·14	·13	·06	. .	. .	. .	. .	. .	. .	.	. .	. .	. .
.	. .	. .	. .	. .	. .	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	·10	·08	·32	1·25	.	. .	. .	.	. .	. .	1·20	. .	. .	. .	. .	. .	. .	. .
63	. .	·46	·65	·09	·12	.	1·55	2.25	1 35	1·68	1·30	·90	2·04	1·55	2·10	1·37	1 35	1·75	1·78
·04	·65	·18	·02	·21	.	.	. .	.	.	. .	. .	·01	.	. .	.	. .	. .	. .	. .
. .	·80	. .	. .	·02	·67	.	. .	. .	.	. .	. .	·30	. .	. .	. .	. .	. .	. .	. .
.	. .	. .	. .	. .	·28	.	·25	. .	. .	.	.	1·88	1.15	. .	. .	·53	. .	·17	. .
. .	.	. .	. .	. .	. .	.	. .	.04	·22	. .	·15	.04	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	.	.	. .	.	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
6·02	6·50	3·51	5·12	4·93	7·36	.	7·31	5.48	3·39	7·91	6·41	7·58	7·54	5.82	5·45	4.49	3·36	5 32	5.28

T. F. T.

PRECIPITATION FOR JUNE, 1889.

Day	Erie.	New Castle.	Greenville.	Columbus.	Pittsburgh.	Uniontown.	Clarion.	Indiana.	Smethport.	Somerset.	Grampian Hills	Emporium.	Phillipsburg.
1	·14	1·05	. .	·34	. .	·04	. .	. .	·50	. .	. .	. .	3.26
2	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	·04	. .	. .	. .	·04	·21	. .	. .	·20	·50	. .	. .	.01
4	·04	1·50	. .	·05	·44	·06	. .	. .	·50	. .	·20	·25	·02
5	.03	. .	. .	·12	·08	·21	. .	. .	·70	. .	·03	·22	·02
6	·02		. .	·08	. .	. .	. .	. .	. .	·02	. .	. .	. .
7	·08	·30	. .	·10	. .	·02	. .	·18	·40	. .	. .	. .	. .
8	·90	. .	. .	·97	·19	·43	. .	·01	·30	. .	·30	·60	·45
9	·24	. .	. .	·12	·06	. .	. .	. .	·40	. .	. .	·16	·08
10	·02	. .	. .	. .	·02	·23	. .	·10	·10	·23	·25	·20	·20
11	. .	·35	·17	.15	·90	·10	. .	·90	·60	. .	·30	·18	·12
12	. .	. .	. .	. .	·08	·21	. .	·25	. .	·30	·18	. .	·20
13	. .	. .	. .	. .	. .	·01	. .	. .	. .	. .	. .	. .	. .
14	·04	. .	·32	·02	·08	·29	. .	·10	. .	·15	. .	. .	. .
15	·32	·50	·23	·51	1·73	·51	. .	·70	. .	·17	·98	·92	·24
16	·99	. .	·62	·50	·04	·27	. .	·02	. .	·25	·06	. .	·05
17	2·15	·57	1·19	·92	·12	1.14	. .	. .	·85	·35	·16	1·02	·16
18	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·20	. .	·25
19	·10	. .	·04	·11	·31	·26	. .	·10	·30	·88	. .	·11	·02
20	·10	. .	. .	·25	. .	·27	. .	. .	. .	. .	·06	. .	·01
21	·14	·78	·20	·13	·20	·78	. .	·28	·75	·30		·47	. .
22	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·45	. .	·35
23	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
25	. .	. .	·10	·08	·32	1·25	. .	·40	. .	·30	. .	. .	. .
26	63	. .	·46	·65	·09	·12	. .	·25	·33	·20	·16	·45	·26
27	·04	·65	·18	·02	·21	. .	. .	. .	. .	·03	·26	05	·01
28	. .	·80	. .	. .	·02	·67	. .	. .	. .	.09	. .	. .	·05
29	. .	. .	. .	. .	. .	·28	. .	. .	. .	. .	·02	. .	·08
30	. .	. .	. .	. .	. .	. .	. .	·10	. .	. .	·10	. .	. .
31	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
	6·02	6·50	3·51	5·12	4·93	7·36	. .	3·39	5·93	3·87	3·71	4·63	5·84

Day	Huntingdon.	Hollidaysburg.	Altoona.	Charlesville.	McConnellsburg.	State College.	York.	New Bloomfield.	Carlisle.	Wellsboro.
1	1·75	39	2·30	·18	·68	1·94	1·70	2·07	1·50	7·45
2	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	·12	·12	. .	·29	·35	·05	·18	. .	. .	. .
4	·96	·05	·03	·13	·45	·64	·46	·90	·52	·10
5	. .	·02	·03	. .	. .	·05	·30	. .	·05	·12
6	. .	. .	·02	. .	. .	. .	. .	. .	. .	. .
7	. .	·05	. .	. .	. .	. .	. .	. .	. .	·05
8	·15	·01	·03	. .	·17	·22	. .	·14	·20	·08
9	. .	. .	. .	. .	. .	. .	. .	. .	. .	·05
10	·04	·14	·05	·08	. .	·08	. .	·06	·05	·12
11	·38	·30	. .	·15	·15	·15	·47	·52	·05	·16
12	·12	·13	·57	·15	·17	·15	·20	·10	·11	·06
13	·01	. .	. .	. .	. .	. .	. .	. .	·01	. .
14	·01	·40	. .	1·93	·86	. .	. .	. .	·08	. .
15	·68	·19	·33	·04	·31	·29	·16	·33	. .	·25
16	. .	·02	·15	. .	. .	·19	·05	. .	·03	. .
17	·31	·02	·03	·20	·41	·80	·15	·29	. .	·65
18	. .	·01	·10	. .	. .	. .	. .	. .	·26	·10
19	·10	·09	·02	·06	·05	·04	. .	. .	. .	·05
20	. .	. .	·34	. .	. .	. .	. .	. .	. .	. .
21	·40	·29	. .	·11	26	·97	·10	·81	. .	·42
22	. .	. .	·44	. .	. .	. .	·80	. .	·73	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
25	·05	·06	. .	·15	·13	. .	·01	·08	·05	·10
26	·07	·29	·23	·26	·20	·18	·35	·80	·65	·15
27	. .	·01	·04	. .	. .	. .	. .	.01	·02	. .
28	·45	. .	. .	·50	·43	·12	. .	·14	·13	·08
29	. .	·12	. .	·03	·56	. .	. .	. .	·15	. .
30	. .	. .	·02	. .	. .	. .	. .	. .	. .	·05
31	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
	5.60	2·71	4·73	4 26	5·17	5 87	5·13	6.25	4·59	10·40

Day	Harrisburg.	Selins Grove.	Wysox.	Girardville.	Myerstown.	Drifton.	Reading.	Pottstown.	West Chester.	Coatesville.	Dyberry.	Coudersport.
1	3·12	1·07	·14	3·05	1·62	·36	2·01	1,00	1·20	1.07	·71	. .
2	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	. .	·06	·35	·02	. .	. .	. .	. .	·03	·02	. .	. .
4	·30	·63	·57	·99	·15	·76	·03	·60	·03	·10	·09	·30
5	·32	·34	·15	·07	·31	. .	·52	. .	·25	·25	·30	·10
6	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
7	. .	. .	·15	. .	. .	. .	. .	. .	. .	. .	. .	. .
8	·08	·05	·20	·06	·09	·11	·04	. .	·03	. .	·32	·10
9	. .	. .	. .	. .	1·01	. .	·01	. .	. .	. .	·05	. .
10	·20	·17	. .	. .	·02	. .	. .	. .	·26	·10	. .	·10
11	·24	·31	·32	·50	·76	·34	·85	·70	·18	·20	·50	·10
12	·12	·10	·01	·19	·13	·12	·11	·20	·81	·30	. .	. .
13	. .	. .	. .	. .	. .	. .	. .	. .	·03	. .	. .	. .
14	. .	. .	·02	. .	. .	. .	. .	. .	·30	·14	. .	. .
15	·75	·21	·12	·36	·16	·10	·53	1·17	·65	1·60	·53	·30
16	. .	. .	·80	. .	. .	. .	. .	. .	·09	. .	·37	·30
17	·31	·29	·52	·47	1·67	·48	·99	·10	·32	·30	·41	·80
18	. .	. .	. .	. .	. .	. .	. .	. .	·04	·02	. .	. .
19	·02	. .	·04	. .	. .	. .	. .	. .	. .	. .	. .	. .
20	. .	. .	. .	. .	. .	. .	·01	. .	. .	. .	. .	. .
21	·18	·30	·95	·27	2·68	·35	. .	·35	·02	·03	·25	2.00
22	·10	. .	. .	. .	·01	·10	·65	. .	·11	·45	. .	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
25	·04	·10	·41	·21	. .	. .	·03	·85	·03	. .	. .	·20
26	·50	·85	·11	1.11	. .	2·06	1·27	1·00	·94	1·11	·71	·50
27	·06	. .	. .	. .	. .	·21	. .	. .	. .	. .	. .	. .
28	.12	·62	. .	·09	. .	. .	·05	. .	. .	. .	. .	. .
29	·72	. .	. .	·56	·05	. .	·99	. .	. .	. .	. .	. .
30	. .	. .	. .	·06	. .	. .	·12	·23	·06	·11	. .	. .
31	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
	7·18	5.10	4·86	8·01	8·66	4·99	8·21	6,20	5.38	5.99	4·24	4 80

Day	Honesdale.	Quakertown.	Swarthmore.	Philadelphia.	Scisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Nesham'y.	Germantown.	Point Pleasant.	Bethlehem.
1	·25	·95	·58	·46	1·93	·98	·19	1,02	·68	1·67	·70	. .	·44	1.00
2	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	. .	·03	. .	·02	. .	. .	·15	·04	. .	. .	. .	·04	. .	. .
4	·12	·04	·02	. .	. .	·09	·13	·06	. .	. .	·03	. .	·01	.22
5	·34	·16	·34	·20	·33	·30	. .	·10	·24	. .	·14	·09	·01	. .
6	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
7	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
8	·32	·04	. .	. .	·48	·05	·05	. .	. .	. .	·01	. .	. .	. .
9	·07	·11	. .	. .	·63	. .	·17	·03	·90	. .	·55	. .	·05	·04
10	. .	. .	. .	. .	. .	. .	. .	. .	. .	·11	. .	. .	. .	. .
11	. .	·44	. .	. .	·72	·32	·84	·31	·26	·22	·20	. .	1·10	·97
12	·02	·35	·60	·43	·10	·33	·12	1 02	·99	·34	. .	1·16	·05	·68
13	·22	·02	·12	. .	. .	·15	. .	. .	. .	. .	·70	. .	. .	. .
14	. .	. .	·68	·04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
15	. .	1·63	·72	·54	·78	1·75	1·18	·76	·56	·92	. .	·54	·50	.71
16	. .	·41	. .	. .	. .	·77	. .	. .	. .	. .	·16	·04	·25	. .
17	·61	1·05	. .	·05	·51	. .	·40	·80	·53	. .	. .	.14	·84	·04
18	. .	·07	. .	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
19	. .	. .	. .	. .	. .	. .	. .	. .	. .	·19	. .	. .	. .	. .
20	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
21	·41	·04	. .	·01	·75	·22	·22	.21	·11	. .	·10	. .	·15	·44
22	. .	·14	·13	·06	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
25	. .	. .	. .	. .	. .	. .	1·00	. .	. .	. .	. .	. .	. .	. .
26	·76	1·55	2.25	1·35	1·68	1·30	·90	2·04	1·55	2·10	1·37	1.35	1·75	1·78
27	·01	. .	. .	. .	. .	. .	·01	. .	. .	. .	. .	. .	. .	. .
28	. .	. .	. .	. .	. .	. .	·30	. .	. .	. .	. .	. .	. .	. .
29	. .	·28	. .	. .	. .	. .	1·88	1.15	. .	. .	·53	. .	·17	. .
30	. .	. .	.04	·22	. .	·15	.04	. .	. .	. .	. .	. .	. .	. .
31	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
	3·13	7·31	5.48	3·39	7·91	6·41	7·58	7·54	5.82	5·45	4.49	3·36	5.32	5.28

T. F. T.

11th, 15th; Coudersport, 21st, 28th; Girardville, 4th, 9th, 28th, 29th; Selins Grove, 4th, 9th, 10th, 15th, 21st, 29th; Somerset, 4th, 16th, 19th; Wellsboro, 15th, 21st, 28th; Columbus, 15th, 16th, 17th, 20th, 21st; Dyberry, 9th, 11th, 15th, 16th, 21st, 29th; York, 11th, 17th, 21st.

Hail.—Dyberry, 15th.

Frost.—Phillipsburg, 24th; Wellsboro, 23d, 24th; Dyberry, 7th; Honesdale, 7th.

Coronæ.—Charlesville, 4th, 11th, 12th; Reading, 15th, 17th; Somerset, 8th, 9th.

Solar Halos.—Charlesville, 21st, 24th, 29th; Reading, 4th, 15th; Pottstown, 4th; Wellsboro, 19th; Dyberry, 3d, 19th, 25th.

Lunar Halos.—Charlesville, 10th; Rimersburg, 9th; Carlisle, 9th, 10th; Indiana, 8th; Wellsboro, 20th.

Auroras.—Greenville, 20th; Girardville, 23d; Selins Grove, 23d.

WEATHER FORECASTS.

Percentage of local verifications of weather and temperature signals as reported by displaymen for June, 1889:

Weather, 76 per cent.
Temperature, 88 per cent.

TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.

Displayman.	*Station.*
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.
W. S. Ravenscroft,	Hyndman.
R. C. Schmidt & Co.,	Belle Vernon.

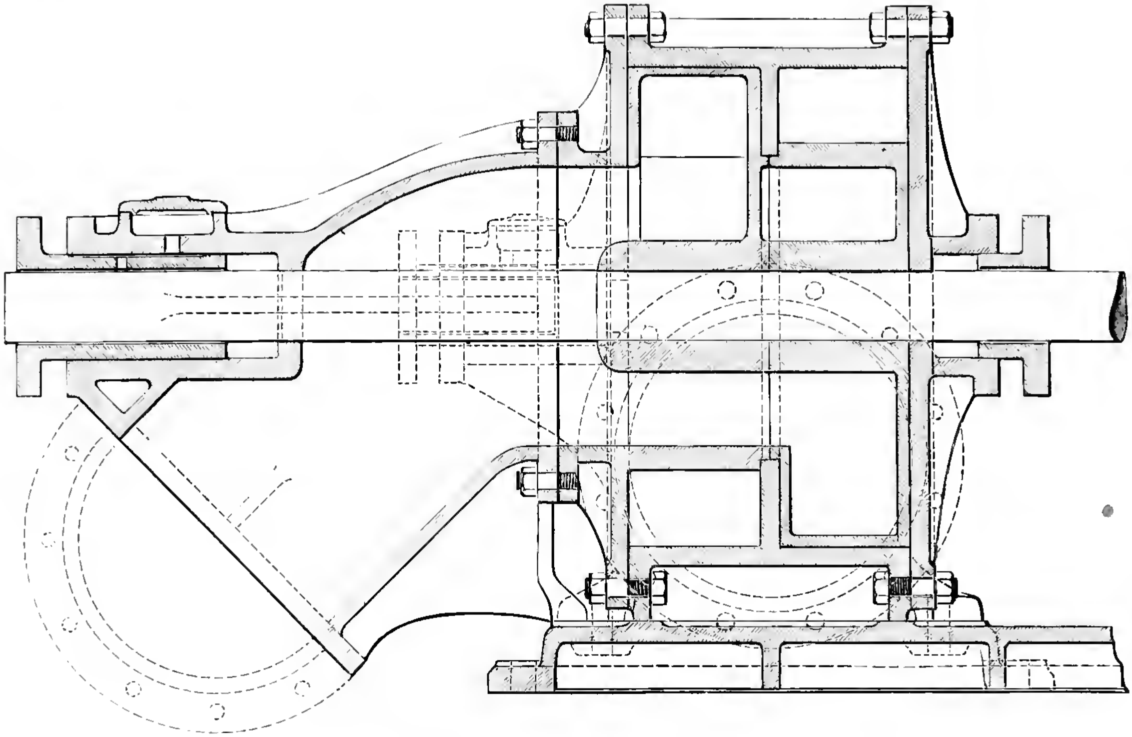


FIG. 2.—Section through Suction.

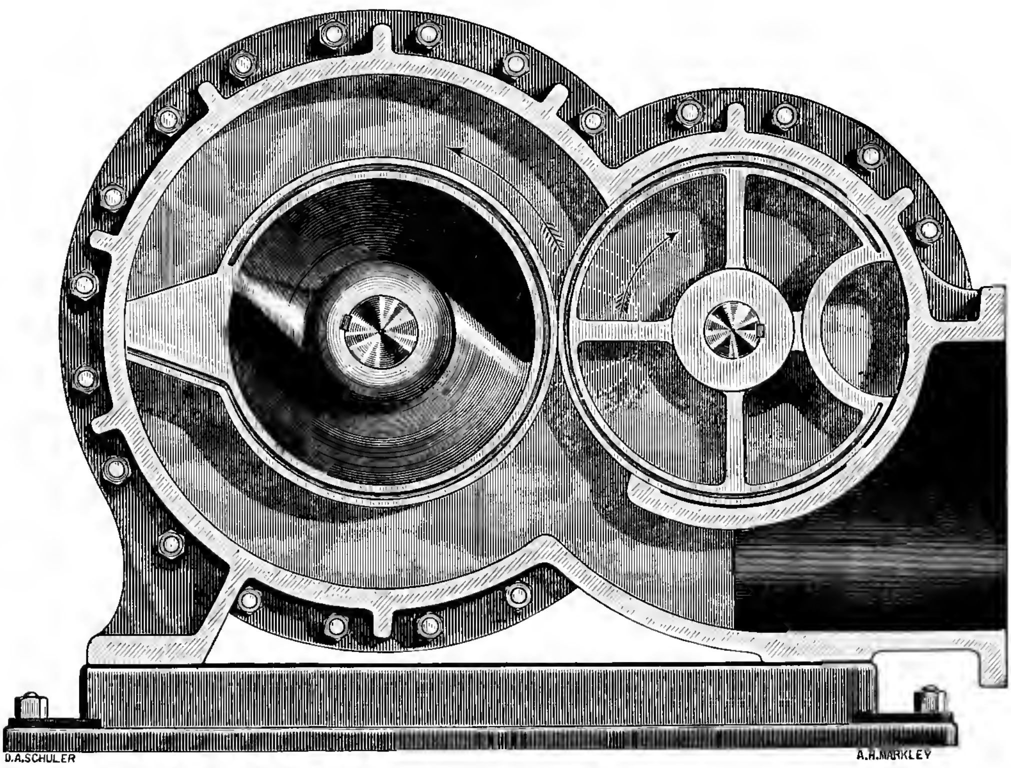


FIG. 3.—Section through Pump Chamber.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVIII. SEPTEMBER, 1889. No. 3.

SOME DIFFICULTIES ENCOUNTERED IN THE OPERATION OF PUMPS, AS MET BY THE "POSITIVE PISTON PUMP."

BY JOSIAH DOW.

To raise a column of fluid, power applied with a pump yields directly effective work in overcoming gravity of the mass, and the friction which is indispensable from necessary contact in pipes and pump chamber. These resistances are obvious necessities, with any method we may employ. In practice, however, other resistances are developed, arising from mechanical methods of construction, which absorb power, often to a great degree, where it yields no effective work, while causing much wear and tear.

The reciprocating system has maintained pre-eminence, because by the piston or "plunger" any desired pressure can be directly applied against the column of fluid to be moved. Were it possible to make this action continuous,

without reversals of reciprocation, no resistances would be met in addition to those noted as inseparable from efficient work, and momentum would become an aiding and equalizing force, as it does with the fly-wheel of a steam engine. But reciprocation converts this force into an active resistant.

Water not being compressible to any appreciable extent, and possessing much weight, through its momentum causes serious difficulties in operating reciprocating pumps, which were expressed by the late Mr. H. R. Worthington, to whom we are so much indebted for improvement in pumping machinery, in these words: "A moment's reflection will show that when the motion of a pump changes, the valves are in the wrong relation thereto, and must be immediately changed. For an instant of time, therefore, the resistance is suspended, much as in the case of a gear suddenly reversed and producing 'backlash.'" Again he wrote, when referring to the valves of a pumping engine: "Before one set can be seated and the other lifted, the engine, by a sudden jump, strikes the water heavily and pounds the valves to their seats. Hence, the noise which always has, and always will, to a greater or less degree, mark the self-destructive action of an ordinary reciprocating pump." Mr. Worthington's remedy was to allow the valves to seat themselves by gravity before beginning the return stroke. This necessitated a very low rate of speed and reduced resistance to the extent that would be realized from a body at rest, instead of moving to meet a momentum. He also appears to have used another means for relieving impact, by making the valve openings of such area that water would not flow fast enough to fill the chamber until after the plunger had come to rest; for he writes: "It reaches the end of its stroke and stops—what follows? The water continues to press, by its momentum, into the chamber, filling every inch of space."

A modification of this practice is a well-known necessity with builders and operators of all reciprocating pumps which move large masses of water. Taking ten of the best known pumping engines in this country, we find a speed of only

eight to nineteen revolutions per minute. Indicator cards taken from water cylinders of such pumping engines, show that those which run at the highest rate of this very moderate speed, exhibit clearly the "water hammer" in its sudden resistance against the plunger. Therefore, to lessen this resistance, a low rate of speed must be maintained. Large air chambers are provided for the same purpose; also the passages and valves must be carefully proportioned to a definite rate of speed.

Small reciprocating pumps often run at higher speeds; in such cases there is much vibration and resistance from impact, with great wear and tear; but, as the containing parts are proportionately strong, these difficulties have assumed position as necessary evils, although the concussions and vibrations may often be heard and felt throughout large buildings. That we may reach some idea of the real value of this destructive work, let us examine:

(1) The physical laws which govern reaction, when motion of a body is arrested.

(2) The results of expert tests, exhibiting value of the reaction in pumps.

(3) Mechanical construction of reciprocating pumps, which causes the reactionary resistance.

For the physical laws it will be sufficient to select three well-known authorities:

From Professor Rankine: "Momentum is the product of the mass of a body into its velocity, in units of distance per second."

"The reaction of a retarded body is as the force required to produce the change of velocity."

From Professor Thurston: "Acceleration and retardation of masses in motion can only be produced by doing work upon them, or by causing them to do work."

"Every mass undergoing retardation must perform work, and thus must restore energy previously communicated to it."

From Weisbach: "There can be no action of a force, without an equal and contrary reaction."

Work performed by a moving mass of water, confined in

a pipe, on coming to rest, is represented by the familiar expression—

$$\tfrac{1}{2} M V^2, \text{ or } \frac{W V^2}{2 g}.$$

Where W represents weight of water in the pipe, in pounds; V its final velocity, in feet per second, and g (gravity) 32·2. The quotient is in units of one second, because V and g are in units of one second; therefore, if the mass is brought to rest in a definite time, the rate of doing work through its momentum will be

$$\frac{W V^2}{2 g T},$$

the unit of T being one second.

E. g., a sixteen-inch suction pipe, forty feet long, contains 3,500 pounds of water; take its motion at the moderate speed of three feet per second, which is arrested within the time of change in direction of a pump plunger, running at fifteen revolutions per minute. This would give $15 \times 2 = 30$ movements of the plunger per minute. Allowing for change in direction one-twentieth of each stroke, or one-tenth of a second (time in which water is brought to rest, as shown by many indicator cards, is often less than this), then is—

$$\frac{3500 \times 3^2}{64{\cdot}4 \times 0{\cdot}1} = 4891{\cdot}3 \text{ foot pounds,}$$

the power by which such a column of water resists being brought to rest in one-tenth of a second. To restore the same degree of motion, in a time equal to that which brought it to rest, requires an equal measure of power.

A familiar illustration of these laws is found in the hydraulic ram, which is analogous, in its useful work, to the destructive work of the "water hammer" in a pump, including application of an air chamber to avoid rupture.

The sudden closing of a cock, after drawing water, under pressure, through it, is also a familiar illustration: To avoid risk from heavy impact, the pipe is usually continued above and beyond the cock, that it may contain an air cushion.

It was shown by experiments made in 1884, and published in *Transactions of American Society of Civil Engineers*

for 1885, that arresting a velocity of 5·36 feet per second, with water in pipes aggregating a length of 272 feet, yielded a force of impact, upon being brought to rest, equal to 129·3 pounds per square inch. More than half of the pipe was very small, which would cause retardation through friction, and prevent a free action at the outlet from momentum of the whole mass. The terminal length was but one inch in diameter.

The report made by a board of experts for testing a large pumping engine at Cincinnati, in 1879, shows that "pressure per superficial inch of pump piston, required to open the suction and delivery valves, in addition to frictional resistance of water passages into and out of the pump, was 13·44 pounds (8·816 inlet, 4·624 outlet). Here, the resistances upon the inlet side of a reciprocating pump are shown to be about double the value of those upon the outlet side. In the record of a series of tests, made in 1885, by engineers of the Philadelphia Water Department, upon a direct-action reciprocating pump, with eight-inch pipes, working against a head of 129 feet, and without suctional lift, there is shown a loss of effective indicated horse-power of thirteen per cent. This was apparently sustained at the outlet side.

By comparing expert tests upon eight of the best known water-works pumps, it is shown that loss of force expended within the water cylinders—ascertained by testing the effective work delivered into water mains by the pump—varied from fourteen to twenty-five per cent., and, in one case, twenty-seven per cent. of the indicated horse-power at the engines. Smaller pumps show much greater percentages of loss. The tests were all made with pumping engines built for the best economy of work, and running at low speed for the purpose of avoiding as much as possible the resistances under discussion. None of them were pumps working in connection with direct distribution, which often necessitates very high pressure and greater speed. Acceleration of speed will rapidly increase losses from arrested momentum, notwithstanding the use of air chambers, because they cannot effect avoidance of the reaction; they receive it as would a spring, to immediately restore it again.

and only lend a partial elasticity, near the point of impact, but not in direct line with it. Indicator cards from the water cylinders show this reaction sometimes, in decreasing vibrations, throughout the whole stroke. Occasionally, at high speed of flow, for a moment, resistance to closing the inlet valves is so great that the current passes directly through both sets of valves, and almost completely blocks the mass of water within the cylinder which the plunger is struggling to remove.

We are now brought to mechanical methods of construction which develop these reactions. The usual form of reciprocating pump, for large masses of water, is that in which a plunger, closely fitting in its travel through the cylinder or water chamber, or through a partition dividing it in two, draws the suction and forces the discharge, alternately at each direction of the travel, acting by displacement. Water can pass into one end or the other of the chamber, to follow the retreating plunger, only through valves opening inward, of which two sets, each for its own end, control the current. A similar arrangement is made with the outlet valves, which are placed at the opposite side of the chamber and open outward. As the plunger retreats in its motion, one set of outlet valves close upon their seats, and atmospheric pressure forces the suction column into the space left for it in the chamber through the opposite inlet valves, while the advancing side of the plunger, having first arrested the suction, presses forward the discharge column. A stroke completed, not only is the motion of the plunger stopped, with weight belonging to itself and connecting parts, but also motion of the water on either side of it and in the pipes; momentum directly opposes this stoppage and the immediately following change in motion of the plunger. At this critical moment for the exertion of power by reciprocation, reaction from momentum is only prevented from becoming a destructive blow, through the use of air chambers. This action and reaction are repeated with every stroke.

Were the valves few and large, they would require a full movement from their seats to admit a sufficient volume of

water, and would cause much loss, through "slip," before a closing could be effected. Consequently they are often small and numerous, with but little lift, to secure quick closing. The partition containing them, when they are closed, offers a complete impediment to the flow, and when open, they remain directly in the way of a subdivided current, while the partition is still an obstruction, together causing not only friction in proportion to the velocity of flow, but also conflicting and churning counter currents, as the streams impinge against the valves, to be deflected radially at sharp angles and to come in contact with each other.

Because impact from momentum increases as the square of the velocity, the limit of speed at which a reciprocating pump, handling large masses of water, can be run safely and economically, is soon reached. This necessitates the use of much larger pumps, at much lower speed, than would be necessary were momentum an aid instead of an obstruction.

The *centrifugal* system of pumping completely avoids obstruction by valves, and develops no concussions through resistance to momentum. Consequently, it permits the movement of large volumes with high rates of speed. A centrifugal pump, however, as the name sufficiently indicates, does not apply power directly to the lifting and moving forward of a column of fluid, and unless water flows to it, or the pipe is first filled, it will draw no suction beyond a very trifling height. The power necessary to drive it increases in a much greater ratio than the heights of delivery. A well-known maker of these pumps has given the following rule for determining the application of power to them: "The amount of power necessary is a function of the height to be attained, multiplied by its square root, or $h\sqrt{h} = \sqrt{h^3}$."

E. g., a pump requires ten horse-power to raise water six feet. It will require, if the height is increased to fifty-four feet, $9 \times \sqrt{9} \times 10 = 270$ horse-power, and not simply the original power multiplied by nine, which would be ninety horse-power.

Although centrifugal pumps depend, for efficient work, upon a high rate of speed, yet there is a limit of speed beyond which their efficiency decreases. This limit, for the outer ends of the fans, is stated by different makers to be from twelve to about twenty-five feet per second. By comparing the best authorities regarding the efficiency of work done by these pumps, we find it to vary from twenty-four to sixty per cent. of the whole power applied, when working against the moderate lift at which they perform their best duty: this for small sizes is about fifteen feet; very large sizes carry their efficiency to higher lifts.

A centrifugal pump is the same in principle, and essentially in construction, as a fan blower. The well-known disproportion of power to useful effect in running fan blowers, for any but a very low pressure of air, is repeated with the pump, except that the pump, as it deals with greater mass, has the advantage of momentum. Discharge from the blower may be completely stopped by a moderate obstruction, notwithstanding a rapid movement of the fans. With the pump, water moving at high speed, through its momentum, would prevent such obstruction without great resistance; but, let the discharge opening be firmly closed and then full motion may set up, while water can fill the pump, but none be discharged from it, and there will be but little force developed from movement of the fans, for they, with the water contained within their periphery, then form a nearly solid and balanced mass, meeting but little resistance to its motion other than that caused by friction with the surrounding parts. This will illustrate the reason why there is always a limit of lift beyond which a centrifugal pump can yield no efficient duty and at last effect no discharge at all. The fact that a fan blower can increase or decrease the pressure of air only within a pound to the square inch, at its best work, sufficiently accounts for the inability of a centrifugal pump to draw its own suction without priming.

Pumps which have been known under the general title of "Rotaries," also avoid, in most of their methods of construction, reaction from momentum and resistance from

valves. They contain one or more sets of rotary vanes or buckets; sometimes intermoving with each other in a similar manner to that of the teeth of gears; sometimes running concentrically with the chamber, like a paddle-wheel in its box; and sometimes sliding in and out of a hub or drum having its periphery in contact, or nearly so, with one side of the chamber. Provision is usually made for automatically closing a radial section of the passage or passages through which the vanes or buckets move, in such manner that they shall not be obstructed, while the current can be carried around through the open portions from the inlet, placed at the outer circumference of the chamber, to the discharge at the opposite side.

There have been various modifications of these general designs, but the greater part of them involve similar principles. The volume of water moved by them is relatively large, but they have not competed successfully with the reciprocating system. There have been several causes for this; such as the difficulties, with their peculiarities of construction, in making their action positive enough without great loss through friction; the paddling effect only of the buckets or vanes following each other, and, when they intergear, the loss of action and the conflicting currents at the retreating parts of the rotation; "pocketing" of water and consequent resistance against the vanes when passing the closed portion of the chamber—often quite serious; a sharp deflection of the current at both inlet and outlet; also, resistance to the inflow, caused by receiving it against centrifugal force, which, with high speeds, becomes a serious obstruction, and the outlet is rarely at a tangent to the circumference of motion, as with centrifugal pumps. Such, and other causes, have prevented economy in power, and many of these pumps, when under full duty, develop troublesome concussions, at even moderately high rates of speed, resulting in much wear and tear.

In 1885 a series of tests were made by the Philadelphia Water Department, upon one of the most successful of the large-volume rotary pumps then in use. Water flowed to the pump, therefore no suctional lift was carried. The

static head to be overcome was about 129 feet. The results were as follows:

Test.	Revolutions Per Minute.	Theoretical Discharge. Gallons.	Actual Discharge. Gallons.	Per Cent Attained.	Indicated Horse-Power.	Effective Horse-Power Calculated from Water Raised.	Per Cent. Effectual Horse Power.
A	20·3	101·5	11·3	10·8	4·26	0·33	8·
X	86·6	433·	452·	104·4	23·06	14·6	63·3
Y	104·7	523·5	536·	102·3	29·82	17·65	59·2

It will be seen that at the lowest speed, A, the effectual percentage of result was very small, in both volume of water and power used. This was doubtless caused by pressure from the column to be raised, 55·86 pounds to the square inch, which was sufficient to cause much loss of water, at this low speed, through the loosely fitted moving parts of the pump, while they were obliged to rotate against the pressure. At the next rate of speed, X, a very different result is attained. The speed has now become sufficient to bring momentum into a useful relation to the flow, which is increased even beyond what displacement in the chamber would indicate. The power applied has also greatly increased in effectiveness. Both appear to have reached their best efficiency.

At the last rate of speed, *Y*, new conditions come into action, and the efficiency in both volume and power is again decreased. This is caused by peculiarities of construction. The speed has increased enough to bring centrifugal force, at the inlet, with the sharp angle at both openings, to bear against the current; also enough to cause an impact of pocketed water against the vanes. These resistances, and consequent loss of power would, doubtless, have grown at a rapidly increasing ratio with higher rates of speed. At the most effective velocity, the loss sustained in effective power was 36·7 per cent.

As percussive action and loss of power, beyond its necessary application to overcome gravity and the small percentage of friction in properly arranged pipes, appear, as we have seen, to arise with the systems considered, except the centrifugal, from structural causes, is it possible to avoid these losses, and the destructive strains which accompany them, by practical changes in construction? Obstructed momentum and excessive friction from subdivision, with conflicting currents, caused by necessity for valves and their sustaining partition, to control the changes in direction of the applied power, are the chief causes of disturbance with reciprocation. We have seen, however, with the other two systems, that momentum may be made a friend instead of an enemy; but they do not exhibit the definite character of work sustained by the reciprocating pumps, which depends upon direct application of power to the piston, or plunger, acting by displacement within its chamber; it is, therefore, evident that in the construction of a pump for full efficiency, this feature must be retained. But it cannot reciprocate without rapidly increasing reaction from momentum; its motion must be in one direction, and this can only be about an axis within the bounds of the chamber. It must still retain full control of displacement, as when in reciprocation, but having made a friend of momentum, it may safely attain a high rate of speed, and thus greatly increase its capacity. Speed will develop centrifugal force, which must also be prevented from becoming an enemy; it may be an aid. To accomplish this, the inlet or suction must be around the axis of motion, as with a centrifugal pump, and the outlet at the periphery of the moving parts as nearly as possible in line with a tangent produced from them. The inflow, being around the axis, will pass between it and the piston, and may be carried into the centre of the pump through a cylinder which will be, in effect, a revolving continuation of the suction pipe, upon which the piston may be placed, and around the outside of which will be the chamber, although annular in shape, practically the same, for action of the piston, as that contained in the reciprocating pump. Centrifugal force will now aid in filling the

chamber, the flow being outward from the revolving cylinder, much as water passes from centre to periphery of a centrifugal pump, except that there will be but one opening, and that placed so that it may fill the chamber through

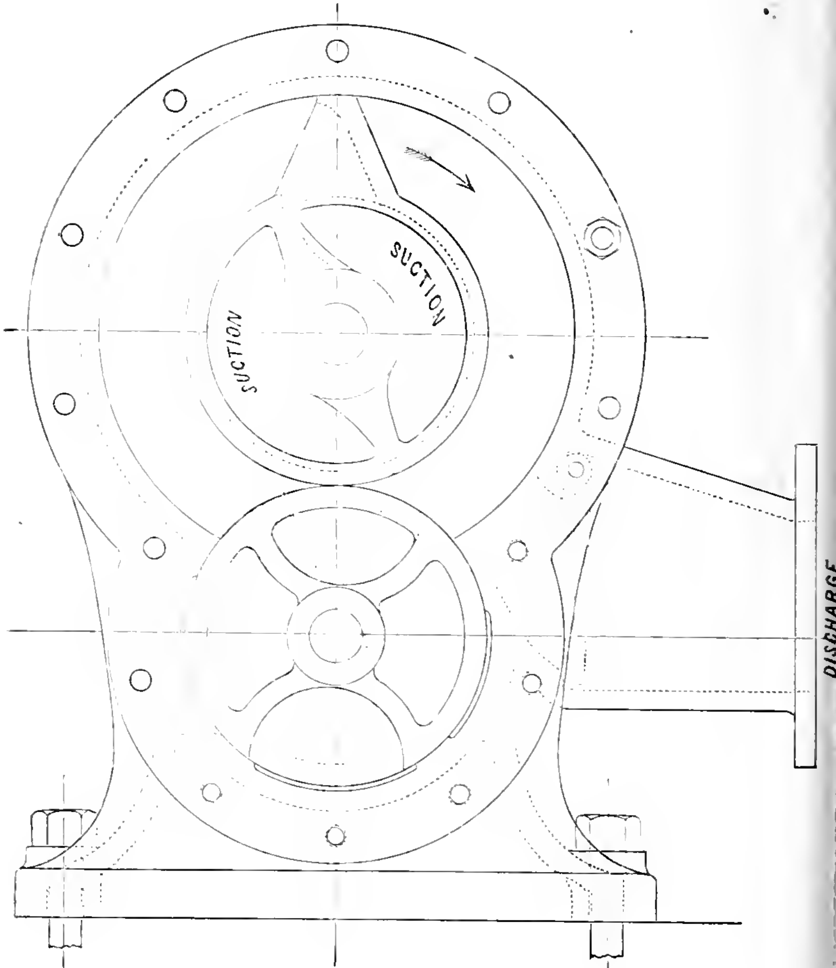


FIG. 1.

the retreating side of the piston, while its advancing side forces the discharge. Without reaction, there can be no action; therefore, no work can be done by the piston, unless the annular chamber be provided with a partition, com-

pletely closing a section of it, to stand in its office as does the head of the cylinder with a reciprocating pump. It must be so constructed as to permit a passage of the piston, without friction, or impact from entrapped water, and to close immediately and firmly behind it. This is effected by a revolving abutment in rolling contact with the cylinder, to which the piston is attached, and with a portion cut away through which it may pass. One piston as described, moving about a central axis, would be unbalanced; therefore, we have two annular chambers, each with its own piston, one balancing the other, and all parts of the pump must have their movement by revolution, and be balanced in action. This construction avoids valves. Water, owing to its momentum and consequent persistence of flow, will not require any, even while the piston passes the abutment. To draw the suction, however, particularly from a considerable depth, the pump then being filled only with air, which is exceedingly elastic, a valve is needed at the outlet to hold the gain in vacuum attained by each stroke of the pistons, until the flow of water is established, when, being hinged at the top, it moves from its seat and can be fastened entirely out of the way, leaving an unobstructed channel. Having secured a free and continuous flow through the pump, which has enlisted as its assistants all the physical forces involved, it will need no air chamber, and will safely attain any desirable rate of speed, against any desirable pressure, with full efficiency of power.

The pump thus described and herewith illustrated in its working parts (see sectional views, *Figs. 1, 2* and *3*), is now being introduced by the Kensington Engine Works, limited, of Philadelphia, under the name of the "Positive Piston Pump." It has repeatedly been put into practical and daily use, with both large and small volumes, high and low lifts, and shows great economy of power, with steady and quiet flow, at high or low speeds. It can be run for moderate lifts without frictional contact of the working parts, the water itself, in grooves, supplying a packing, and momentum preventing slip, or it can be packed with a self-lubricating packing to prevent slip at any speed or pressure. It

will readily establish its own suction, through use of the suction valve in the discharge, and yet leave the passage perfectly free for the flow of water. It is a small pump, relatively to the large volume of fluid moving through it, which may be increased with every accession of speed.

The same construction, with little modification, has been used as a pressure blower and air compressor, with very satisfactory results. It has the great advantage not only of fast movement, but no trouble arising from condensed and entrapped water.

ALUMINIUM.

By Sir Henry Roscoe, M.P., D.C.L., LL.D., F.R.S.

[*A Discourse delivered at the Royal Institution, London, Friday, May 3, 1889.*]

Chemists of many lands have contributed to our knowledge of the metal aluminium. Davy, in 1807, tried in vain to reduce alumina by means of the electric current. Oerstedt, the Dane, in 1824, pointed out that the metal could be obtained by treating the chloride with an alkali metal; this was accomplished in Germany by Wöhler in 1827, and more completely in 1845, whilst in 1854 Bunsen showed how the metal can be obtained by electrolysis. But it is to France, by the hands of Henri St. Claire Deville, in the same year, that the honor belongs of having first prepared aluminium in a state of purity, and of obtaining it on a scale which enabled its valuable properties to be recognized and made available, and the bar of "silver-white metal from clay," was one of the chemical wonders in the first Paris Exhibition of 1855. Now England and America step in, and I have this evening to relate the important changes which further investigation has effected in the metallurgy of aluminium. The process suggested by Oerstedt, carried out by Wöhler, and modified by Deville, remains in principle unchanged. The metal is prepared, as before, by a

reduction of the double chloride of aluminium and sodium, by means of metallic sodium in presence of cryolite; and it is, therefore, not so much a description of a new reaction as of improvements of old ones of which I have to speak.

I may perhaps be allowed to remind my hearers that more than thirty-three years ago, Mr. Barlow, then Secretary to the Institution, delivered a discourse, in the presence of M. Deville, on the properties and mode of preparation of aluminium, then a novelty. He stated that the metal was then sold at the rate of £3 per ounce, and the exhibition of a small ingot, cast in the laboratory by M. Deville, was considered remarkable. As indicating the progress since made, I may remark that the metal is now sold at twenty shillings per pound, and manufactured by the ton, by the Aluminium Company, at their works at Oldbury, near Birmingham. The improvements which have been made in this manufacture by the zeal and energy of Mr. Castner, an American metallurgist, are of so important a character, that the process may properly be termed the Deville-Castner process.

The production of aluminium previous to 1887, probably did not exceed 10,000 pounds per annum, whilst the price at that time was very high. To attain even this production required that at least 100,000 pounds of double chloride, and 40,000 pounds of sodium should be manufactured annually. From these figures an idea of the magnitude of the undertaking assumed by the Aluminium Company may be estimated, when we learn that they erected works having an annual producing capacity of 100,000 pounds of aluminium. To accomplish this, required not only that at least 400,000 pounds of sodium, 800,000 pounds of chlorine, and 1,000,000 pounds of double chloride, should be annually manufactured, but in addition that each of these materials should be produced at a very low cost, in order to enable the metal to be sold at twenty shillings per pound.

Annexed is a sketch plan of the works, which now cover a space of nearly five acres. They are divided into five separate departments, viz:

(1) Sodium.

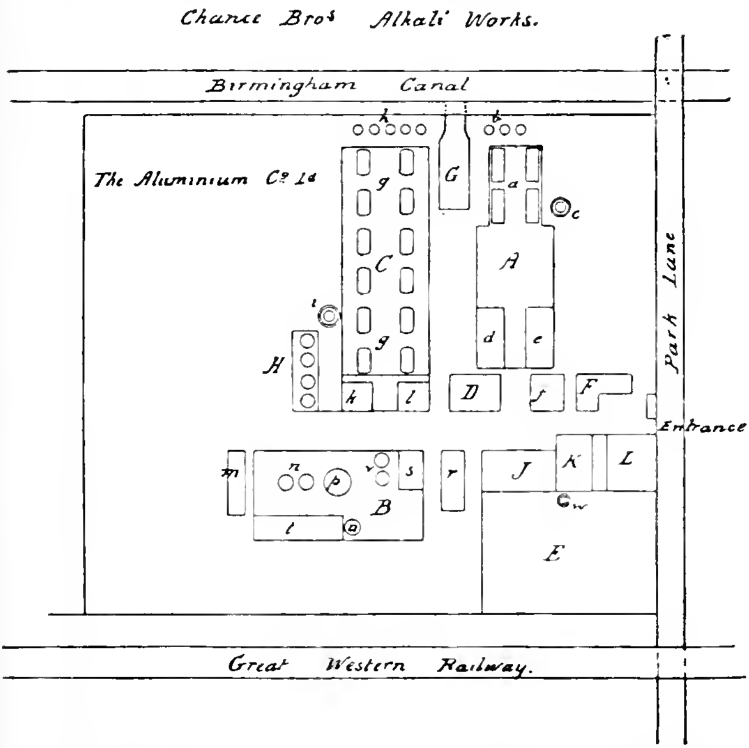
(2) Chlorine.
(3) Chloride.
(4) Aluminium.
(5) Foundry, rolling, wire mills, etc.

In each department an accurate account is kept of the production each day, the amount of material used, the different furnaces and apparatus in operation, etc. In this manner it has been found possible to ascertain each day exactly how the different processes are progressing, and what effect any modification has, either on cost, quantity, or quality of product. By this means a complicated chemical process is reduced to a series of very simple operations, so that whilst the processes are apparently complicated and difficult to carry out successfully, this is not the case now that the details connected with the manufacture have been perfected, and each operation carried on quite independently until the final materials are brought together for the production of the aluminium.

MANUFACTURE OF SODIUM.

The first improvement occurs in the manufacture of sodium by what is known as the "Castner Process." The successful working of this process marks an era in the production of sodium, as it not only has greatly cheapened the metal, but also has enabled the manufacture to be carried out upon a very large scale with little or no danger. Practically the process consists in heating fused caustic soda in contact with carbon whilst the former substance is in a perfectly liquid condition. By the process in vogue before the introduction of this method, it was always deemed necessary that special means should be taken to guard against actual fusion of the mixed charges, which, if it were to take place, would to a large extent allow the alkali and reducing material to separate. Thus having an infusible charge to heat, requiring the employment of a very high temperature for its decomposition, the iron vessels must be of small circumference to allow the penetration of the heat to the centre of the charge without actually melting the vessel in which the materials are heated. By the new process, owing to the

alkali being in a fused or perfectly liquid condition in contact directly with carbon, the necessity of this is avoided,



A. Sodium works.
B. Chlorine works.
C. Double chloride works.
D. Aluminium furnaces.
E. Rolling mills, etc.
F. Offices and laboratory.
G. Arm of canal.
H. Chlorine gasometers.
J. Wire mill.
K. Foundry.
L. Warehouse.
a. Sodium furnaces.
b. Gas producers.
c. Chimney, 150 feet high, 7 feet diameter inside.
d. Sodium casting and storage.
f. Supplies for sodium works.
g. Chloride furnaces.
h. Gas producers.
i. Chimney, 180 feet high, 10 feet diameter inside.
k. Mixing room for balls.
l. Purifying and storing chloride.
m. Storage vats for acid.
n. Chlorine stills.
p. Neutralizing well.
u. Oxidizing tower.
t. Settling tanks.
v. Lime vats.
s. Boilers.
r. Blowing engine.
w. Chimney.
e. Engine and boiler rooms.

and consequently, the reduction can be carried on in large vessels at a comparatively low temperature. The reaction taking place may be expressed as follows:

$$3NaHO + C = Na_2CO_3 + 3H + Na.$$

The vessels in which the charges of alkali and reducing material are heated are of egg-shaped pattern, about eighteen inches in width at their widest part and about three feet high, and are made in two portions, the lower one being actually in the form of a crucible, while the upper one is provided with an upright stem and a protruding hollow arm. This part of the apparatus is known as the cover. In commencing the operation, these covers are raised in the heated furnace through apertures provided in the floor of the heated chamber, and are then fastened in their place by an attachment adjusted to the stem; the hollow arm extends outside the furnace. Directly below each aperture in the bottom of the furnace are situated the hydraulic lifts, attached to the top of which are the platforms upon which are placed the crucibles to be raised into the furnace. Attached to the hydraulic lifts are the usual reversing valves for lowering or raising, and the platform is of such a size as, when raised, completely to fill the bottom aperture of the furnace. The charged crucible, being placed upon the platform, is raised into its position, the edges meeting those of the cover, forming an air-tight joint which prevents the escape of gas and vapor from the vessel during reduction, except by the hollow arm provided for this purpose. The natural expansion of the iron vessels is accommodated by the water pressure in the hydraulic lifts, so that the joint of the cover and crucible are not disturbed until it is intended to lower the lift for the purpose of removing the crucible.

The length of time required for the first operation of reduction and distillation is about two hours. At the end of this time the crucibles are lowered, taken from the platforms by a large pair of tongs on wheels, carried to a dumping pit, and thrown on their sides. The residue is cleaned out, and the hot pot, being again gripped by the tongs, is

taken back to the furnace. On its way, the charge of alkali and reducing material is thrown in. It is again placed on the lift and raised in position against the edges of the cover. The time consumed in making the change is one and one-half minute, and it requires only about seven minutes to draw, empty, recharge, and replace the five crucibles in each furnace. In this manner the crucibles retain the greater amount of their heat, so that the operation of reduction and distillation now requires only one hour and ten minutes. Each of the four furnaces, of five crucibles each, when in operation, is drawn alternately, so that the process is carried on night and day.

Attached to the protruding hollow arm from the cover are the condensers, which are of a peculiar pattern specially adapted to this process, being quite different from those formerly used. They are about five inches in diameter, and nearly three feet long, and have a small opening in the bottom about twenty inches from the nozzle. The bottom of these condensers is so inclined that the metal condensed from the vapor issuing from the crucible during reduction, flows down and out into a small pot placed directly below this opening. The uncondensed gases escape from the condenser at the further end, and burn with the characteristic sodium flame. The condensers are also provided with a small hinged door at the further end, by means of which the workmen from time to time may look in to observe how the distillation is progressing. Previous to drawing the crucibles from the furnace for the purpose of emptying and recharging, the small pots containing the distilled metal are removed, and empty ones substituted. Those removed each contain on an average about six pounds of metal, and are taken directly to the sodium casting shop, where it is melted and cast, either into large bars ready to be used for making aluminium, or in smaller sticks to be sold.

Special care is taken to keep the temperature of the furnaces at about 1,000° C., and the gas and air valves are carefully regulated, so as to maintain as even a temperature as possible. The covers remain in the furnace from Sunday

night to Saturday afternoon, and the crucibles are kept in use until they are worn out, when new ones are substituted without interrupting the general running of the furnace. A furnace in operation requires 250 pounds of caustic soda every one hour and ten minutes, and yields in the same time thirty pounds of sodium, and about 240 pounds of crude carbonate of soda. With the four furnaces at work 120 pounds of sodium can be made every seventy minutes or over a ton in the twenty-four hours. The residual carbonate, on treatment with lime in the usual manner, yields two-thirds of the original amount of caustic operated upon. The sodium, after being cast, is saturated with kerosene oil, and stored in large tanks holding several tons, placed in rooms specially designed for security against either fire or water.

CHLORINE MANUFACTURE.

This part of the works is connected with the adjacent works of Messrs. Chance Brothers, by a large gutta-percha pipe, by means of which, from time to time, hydrochloric acid is supplied direct into the large storage cisterns, from which it is used as desired for making the chlorine. For the preparation of the chlorine gas needed in making the chloride, the usual method is employed; that is, hydrochloric acid and manganese dioxide are heated together, when chlorine gas is evolved with effervescence, and is led away by earthenware and lead pipes to large lead-lined gasometers, where it is stored.

The materials for the generation of the chlorine are brought together in large tanks, or stills, built up out of great sandstone slabs, having rubber joints, and the heating is effected by the injection of steam. The evolution of gas, at first rapid, becomes gradually slower, and at last stops; the hydrochloric acid and manganese dioxide being converted into chlorine and manganous chloride. This last compound remains dissolved in the "spent still liquor" and is reconverted into manganese dioxide, to be used over again, by Weldon's manganese recovery process. Owing to the difficulty of keeping up a regular supply of chlorine

under a constant pressure directly from the stills, in order that the quantity passed into the sixty different retorts in which the double-chloride is made can be regulated and fed as desired, four large gasometers were erected. Each of these is capable of holding 1,000 cubic feet of gas, and is completely lined with lead, as are all the connecting mains, etc., this being the only available metal which withstands the corrosive action of chlorine. The gasometers are filled in turn from the stills, the chlorine consumed being taken direct from a gasometer under a regular pressure until it is exhausted, the valves being changed, the supply is taken from another holder, the empty one being refilled from the still.

MANUFACTURE OF THE DOUBLE CHLORIDE.

Twelve large regenerative gas furnaces are used for heating, and in each of these are fixed five horizontal fire-clay retorts about ten feet in length, into which the mixture for making the double chloride is placed. These furnaces have been built in two rows, six on a side, the clear passage-way down the centre of the building, which is about 250 feet long, being fifty feet in width. Above this central passage is the staging, carrying the large lead mains for the supply of the chlorine coming from the gasometers. Opposite each retort and attached to the main, are situated the regulating values, connected with lead and earthenware pipes, for the regulation and passage of the chlorine to each retort. The valves are of peculiar design, and have been so constructed that the chlorine is made to pass through a certain depth of liquid, which not only by opposing a certain pressure allows a known quantity of gas to pass in a given time, but also prevents any return from the retort into the main, should an increase of pressure be suddenly developed in the retorts.

The mixture with which the retorts are charged is made by grinding together hydrate of alumina, salt, and charcoal. This mixture is then moistened with water, which partially dissolves the salt, and thrown into a pug mill of the usual type for making drain pipes, excepting that the mass is

forced out into solid cylindrical lengths upon a platform alongside of which a workman is stationed with a large knife, by means of which the material is cut into lengths of about three inches each. These are then piled on top of the large furnaces to dry. In a few hours they have sufficiently hardened to allow of their being handled. They are then transferred to large wagons, and are ready to be used in charging the retorts.

The success of this process is in a great measure dependent:

(1) On the proportionate mixture of materials.

(2) On the temperature of the furnace.

(3) On the quantity of chlorine introduced in a given time.

(4) On the actual construction of the retorts.

I am, however, not at liberty to discuss the details of this part of the process, which have only a commercial interest. In carrying on the operation, the furnaces or retorts, when at the proper temperature, are charged by throwing in the balls until they are quite full, the fronts are then sealed up, and the charge allowed to remain undisturbed for about four hours, during which time the water of the alumina hydrate is completely expelled. At the end of this time the valves on the chlorine main are opened, and the gas is allowed to pass into the charged retorts. In the rear of each retort, and connected therewith by means of an earthenware pipe, are the condenser boxes, which are built in brick. These boxes are provided with openings or doors and also with earthenware pipes, connected with a small flue for carrying off the uncondensed vapors to the large chimney. At first the chlorine passed into each retort is all absorbed by the charge, and only carbonic oxide escapes into the open boxes, where it burns. After a certain time, however, dense fumes are evolved, and the boxes are then closed, while the connecting pipe between the box and the small flue serves to carry off the uncondensed vapors to the chimney.

The reaction which takes place is as follows:

$$Al_2O_3 + 2NaCl + 3C + 6Cl = 2AlCl_3NaCl + 3CO.$$

The chlorine is passed in for about seventy-two hours in varying quantity, the boxes at the back being opened from time to time by the workmen to ascertain the progress of the distillation. At the end of the time mentioned the chlorine valves are closed and the boxes at the back of the furnace are all thrown open. The crude double chloride, as distilled from the retorts, condenses in the connecting pipe and trickles down into the boxes, where it solidifies in large irregular masses. The yield from a bench of five retorts will average from 1,600 to 1,800 pounds, which is not far from the theoretical quantity. After the removal of the crude chloride from the condenser boxes, the retorts are opened at their charging end, and the residue, which consists of a small quantity of alumina, charcoal and salt is raked out and remixed in certain proportions with fresh material, to be used over again. The furnace is immediately re-charged and the same operations repeated, so that from each furnace upwards of 3,500 pounds of chloride are obtained weekly. With ten of the twelve furnaces always at work, the plant is easily capable of producing 30,000 pounds of chloride per week, or 1,500,000 pounds per annum.

Owing to the presence of iron, both in the materials used (viz., charcoal, alumina, etc.) and in the fire-clay composing the retorts, the distilled chloride always contains a varying proportion of this metal in the form of ferrous and ferric chlorides. When it is remembered that it requires ten pounds of this chloride to produce one pound of aluminium by reduction, it will be quite apparent how materially a very small percentage of iron in the chloride will influence the quality of the resulting metal. I may say that, exercising the utmost care as to the purity of the alumina and the charcoal used, and after having the retorts made of special fire-clay containing only a very small percentage of iron, it was found almost impossible to produce upon a large scale a chloride containing less than 0·3 per cent. of iron.

This crude double chloride, as it is now called at the works, is highly deliquescent, and varies in color from a light yellow to a dark red. The variation in color is not

so much due to the varying percentage of iron contained, as to the relative proportion of ferric or ferrous chlorides present, and although a sample may be either very dark or quite light, it may still contain only a small percentage of iron if it be present as ferric salt, or a very large percentage if it is in the ferrous condition. Even when exercising all possible precautions, the average analysis of the crude double chloride shows about 0·4 per cent. of iron. The metal subsequently made from this chloride, therefore, never contained much less than about five per cent. of iron, and as this quantity greatly injures the capacity of aluminium for drawing into wire, rolling, etc., the metal thus obtained required to be refined. This was successfully accomplished by Mr. Castner and his able assistant, Mr. Cullen, and for some time all the metal made was refined, the iron being lowered to about two per cent.

The process, however, was difficult to carry out, and required careful manipulation, but as it then seemed the only remedy for effectively removing the iron, it was adopted and carried on for some time quite successfully, until another invention of Mr. Castner rendered it totally unnecessary. This consisted in purifying the double chloride before reduction. I cannot now explain this process, but I am able to show some of the product. This purified chloride, or pure double chloride, is, as you see, quite white, and is far less deliquescent than the crude, so that it is quite reasonable to infer that this most undesirable property is greatly due to the former presence of iron chlorides. I have seen large quantities containing upwards of one and one-half per cent. of iron, or 150 pounds to 10,000 of the chloride, completely purified from iron in a few minutes, so that, whilst the substance before treatment was wholly unfit for the preparation of aluminium, owing to the presence of iron, the result was, like the sample exhibited, a mass containing only one pound of iron in 10,000, or 0·01 per cent. The process is extremely simple, and adds little or no appreciable cost to the final product. After treatment this pure chloride is melted in large iron pots and run into drums similar to those used for storing caustic soda. As

far as I am aware, it was generally believed to be an impossibility to remove the iron from anhydrous double chloride of aluminium and sodium, and few, if any, chemists have ever seen a pure white double chloride.

ALUMINIUM MANUFACTURE.

I now come to the final stage of the process, viz., the reduction of the pure double chloride by sodium. This is effected, not in a tube of Bohemian glass, as shown in Mr. Barlow's lecture in 1856, but in a large reverberatory furnace, having an inclined hearth about six feet square, the inclination being towards the front of the furnace, through which are several openings at different heights. The pure chloride is ground together with cryolite in about the proportions of two to one, and is then carried to a staging erected above the reducing furnace. The sodium, in large slabs or blocks, is run through a machine similar to an ordinary tobacco-cutting machine, where it is cut into small thin slices; it is then also transferred to the staging above the reducing furnace.

Both materials are now thrown into a large revolving drum, when they become thoroughly mixed. The drum being opened and partially turned, the contents drop out into a car on a tramway directly below. The furnace having been raised to the desired temperature, the dampers of the furnace are all closed to prevent the access of air, the heating gas also being shut off. The car is then moved out on the roof of the furnace until it stands directly over the centre of the hearth. The furnace roof is provided with large hoppers, and through these openings the charge is introduced as quickly as possible. The reaction takes place almost immediately, and the whole charge quickly liquefies. At the end of a certain time the heating gas is again introduced and the charge kept at a moderate temperature for about two hours. At the end of this period the furnace is tapped by driving a bar through the lower opening, which has previously been stopped with a fire-clay plug, and the liquid metal run out in a silver stream into moulds placed below the opening. When the metal has all

been drawn off, the slag is allowed to run out into small iron wagons and removed. The openings being again plugged up, the furnace is ready for another charge. From each charge, composed of about 1,200 pounds of pure chloride, 600 pounds of cryolite, and 350 pounds of sodium, about 115 to 120 pounds of aluminium is obtained.

The purity of the metal entirely depends upon the purity of the chloride used, and without exercising more than ordinary care the metal tests usually indicate a purity of metal above ninety-nine per cent. On the table is the metal run from a single charge, its weight is 116 pounds, and its composition, as shown by analysis, is 99·2 aluminium, 0·3 silicon and 0·5 iron. This I believe to be the largest and the purest mass of metal ever made in one operation.

The result of eight or nine charges are laid on one side, and then melted down in the furnace to make a uniform quality, the liquid metal, after a good stirring, being drawn off into moulds. These large ingots, weighing about sixty pounds each, are sent to the casting shop, there to be melted and cast into the ordinary pigs, or other shapes, as may be required for the making of tubes, sheets, or wire, or else used directly for making alloys of either copper or iron.

The following table shows approximately the quantity of each material used in the production of one ton of aluminium:

Metallic sodium, ...	6,300 pounds.
Double chloride, ...	22,400 "
Cryolite, ...	8,000 "
Coal, ...	8 tons.

To produce 6,300 pounds of sodium is required:

Caustic soda, ...	44,000 pounds.
Carbide made from pitch, 12,000 pounds, and iron turnings, 1,000 pounds, ...	7,000 "
Crucible castings, ...	2½ tons.
Coal, ...	75 "

For the production of 22,400 pounds of double chloride is required:

Common salt, ...	8,000 pounds.
Alumina hydrate, ...	11,000 "
Chlorine gas, ...	15,000 "
Coal, ...	180 tons.

For the production of 15,000 pounds of chlorine gas is required:

Hydrochloric acid,	180,000 pounds.
Limestone dust,	45,000 "
Lime,	30,000 "
Loss of manganese,	1,000 "

(These figures were rendered more evident by the aid of small blocks, each cut a given size so as to represent the relative weights of the different materials used to produce one unit of aluminium.)

It might seem, on looking over the above numbers, as if an extraordinary amount of waste occurred, and as if the production is far below that which ought to be obtained, but a study of the figures will show that this is not the case. I would wish to call attention to one item in particular, viz., fuel, it having been remarked that the consumption of coal must prevent cheap production. I think when it is remembered that coal, such as used at the works, cost only four shillings per ton, while the product is worth £2,240 per ton, the cost of coal is not an item of consequence in the cost of production. The total cost of the coal to produce one ton of metal being £50; the actual cost for fuel is less than sixpence for every pound of aluminium produced. The ratio of cost of fuel to value of product is indeed less than is the case in making either iron or steel. In concluding my remarks as to the method of manufacture and the process in general, I may add that I do not think it is too much to expect, in view of the rapid strides already made, that in the future, further improvements and modifications will enable aluminium to be produced and sold even at a lower price than appears at present possible.

PROPERTIES OF ALUMINIUM.

In its physical properties aluminium widely differs from all the other metals. Its color is a beautiful white, with a slight blue tint. The intensity of this color becomes more apparent when the metal has been worked, or when it contains silicon or iron. The surface may be made to take a very high polish, when the blue tint of the metal becomes

manifest, or it may be treated with caustic soda and then nitric acid, which will leave the metal quite white. The extensibility or malleability of aluminium is very high, ranking with gold and silver if the metal be of good quality. It may be beaten out into thin leaf quite as easily as either gold or silver, although it requires more careful annealing.

It is extremely ductile and may be easily drawn, especial care being required only in the annealing.

The excessive sonorousness of aluminium is best shown by example (large suspended bar being struck). Faraday has remarked, after experiments conducted in his laboratory, that the sound produced by an ingot of aluminium is not simple, and one may distinguish the two sounds by turning the vibrating ingot.

After being cast it has about the hardness of pure silver, but may be sensibly hardened by hammering.

Its tensile strength varies between twelve and fourteen tons to the inch (test sample which was shown having been broken at thirteen tons or 27,000 pounds), ordinary cast iron being about eight tons. Comparing the strength of aluminium in relation to its weight, it is equal to steel of thirty-eight tons tensile strength. The specific gravity of cast aluminium is 2·58, but after rolling or hammering this figure is increased to about 2·68.

The specific gravity of aluminium being one, copper is 3·6, nickel 3·5, silver 4, lead 4·8, gold 7·7.

The fusibility of aluminium has been variously stated as being between that of zinc and silver, or between 600 and 1,000° C.

As no reliable information has ever been made public on this subject, my friend, Professor Carnelley, undertook to determine it. I was aware from information gained at the works at Oldbury, that a small increase in the percentage of contained iron materially raised its point of fusion, and it has been undoubtedly due to this cause that such wide limits are given for the melting point. Under these circumstances two samples were forwarded for testing, of which No. 1, containing one-half per cent. of iron, had a melting

point of 700° C.; whereas No. 2, containing five per cent. of iron, does not melt at 700° and only softens somewhat above that temperature, but undergoes incipient fusion at 730°.

According to Faraday, aluminium ranks very high among metallic conductors of heat and electricity, and he found that it conducted heat better than either silver or copper. The specific heat is also very high, which accounts for length of time required for an ingot of the metal to either melt or get cold after being cast.

Chemically, its properties are well worthy of study.

Air, either wet or dry, has absolutely no effect on aluminium at the ordinary temperature, but this property is only possessed by a very pure quality of metal, and the pure metal in mass undergoes only slight oxidation even at the melting point of platinum.

Thin leaf, however, when heated in a current of oxygen, burns with a brilliant, bluish white light. (Experiment shown.) If the metal be pure, water has no effect on it whatever, even at a red-heat. Sulphur and its compounds also are without action on it, while, under the same circumstances, nearly all metals would be discolored with great rapidity. (Experiment shown using silver and aluminium under the same conditions.)

Dilute sulphuric acid and nitric acid, both diluted and concentrated, have no effect on it, although it may be dissolved in either hydrochloric acid or caustic alkali. Heated in an atmosphere of chlorine it burns with a vivid light, producing aluminium chloride. (Experiment shown.) In connection with the subject it may be of interest to state the true melting point of the double chloride of aluminium and sodium, which has always been given at 170° to 180° C., but which Mr. Baker, the chemist to the works, finds lies between 125° and 130° C.

USES OF ALUMINIUM.

Its uses, unalloyed, have heretofore been greatly restricted. This is, I believe, owing only to its former high price, for no metal possessing the properties of

aluminium could help coming into larger use if its cost were moderate. Much has been said as to the impossibility of soldering it being against its popular use, but I believe that this difficulty will now soon be overcome. The following are a few of the purposes to which it is at present put: telescope tubes, marine glasses, eye-glasses and sextants, especially on account of its lightness. Fine wire for the making of lace, embroidery, etc. Leaf in the place of silver leaf, sabre sheaths, sword handles, etc., statuettes and works of art, jewelry and delicate physical apparatus, culinary utensils, harness fittings, metallic parts of soldiers' uniforms, dental purposes, surgical instruments, reflectors (as it is not tarnished by the products of combustion), photographic apparatus, aëronautical and engineering purposes, and especially for the making of alloys.

ALLOYS OF ALUMINIUM.

The most important alloys of aluminium are those made with copper. These alloys were first prepared by Dr. Percy, in England, and now give promise of being largely used. The alloy produced by the addition of ten per cent. of aluminium to copper, the maximum amount that can be used to produce a satisfactory alloy, is known as aluminium bronze. Bronzes, however, are made which contain smaller amounts of aluminium, possessing in a degree the valuable properties of the ten per cent. bronze. According to the percentage of aluminium up to ten per cent., the color varies from red gold to pale yellow. The ten per cent. alloy takes a fine polish, and has the color of jewellers' gold. The five per cent. alloy is not quite so hard, the color being very similar to that of pure gold. I am indebted to Prof. Roberts Austen for a splendid specimen of crystallized gold, as also for a mould in which the gold at the mint is usually cast, and in this I have had prepared ingots of the ten and five per cent. alloy, so that a comparison may be made of the color of these with a gold ingot cast in the same mould, for the loan of which I have to thank Messrs. Johnson, Matthey & Co. (specimens shown).

I have also ingots of the same size, of pure aluminium,

from which an idea of the relative weights of gold and aluminium may be obtained.

To arrive at perfection in the making of these alloys, not only is it required that the aluminium used should be of good quality, but also that the copper must be of the very best obtainable. For this purpose only the best brands of Lake Superior copper should be used. Inferior brands of copper or any impurities in the alloy give poor results. The alloys all possess a good color, polish well, keep their color far better than all other copper alloys, are extremely malleable and ductile, can be wrought either hot or cold, easily engraved, the higher grades have an elasticity exceeding steel, are easily cast into complicated forms, do not lose in remelting, and are possessed of great strength, dependent, of course, on the purity and percentage of contained aluminium. The ten per cent. alloy, when cast, has a tensile strength of between 70,000 and 80,000 pounds per square inch, but when hammered or wrought, the test exceeds 100,000 pounds. (A sample shown broke at 105,000 pounds.)

An attempt to enumerate either the present uses or the possible future commercial value of these alloys is beyond my present purpose. I may, however, remark that they are not only adapted to take the place of bronze, brass and steel, but they also so far surpass all of those metals, both physically and chemically, as to make their extended use assured. (Sheets, rods, tubes, wire and ingots shown.)

But even a more important use of aluminium seems to be its employment in the iron industry, of which it promises shortly to become a valuable factor, owing to certain effects which it produces when present, even in the most minute proportions. Experiments are now being carried on at numerous iron and steel works, in England, on the Continent and in America. The results, so far attained, are greatly at variance, for whilst in the majority of cases the improvements made have encouraged the continuance of the trials, in others the result has not been satisfactory. On this point I would wish to say to those who may contemplate making use of aluminium in this direction, that it

would be advisable, before making their experiments, to ascertain whether the aluminium alloy they may purchase actually contains any aluminium at all, for some of the so-called aluminium alloys contain little or no aluminium, and this would doubtless account for the negative results obtained. Again, others contain such varying proportions of carbon, silicon and other impurities, as to render their use highly objectionable.

It seems to be a prevailing idea with some persons, that because aluminium is so light compared with iron, it cannot be directly alloyed, and furthermore, that for the same reason, alloys made by the direct melting together of the two metals would not be equal to an alloy where both metals are reduced together. Now, of course, this is not the case, and the statement has been put forward by those who were able to make the alloys in one way only.

Aluminium added to molten iron and steel lowers their melting points, consequently increases the fluidity of the metal, and causes it to run easily into moulds and set there without entrapping air and other gases, which serve to form blow-holes and similar imperfections. It is already used by a large number of steel founders, and seems to render the production of sound steel castings more certain and easy than is otherwise possible.

One of the most remarkable applications of this property which aluminium possesses of lowering the melting-point of iron, has been made use of by Mr. Nordenfelt in the production of castings of wrought iron.

Aluminium forms alloys with most other metals, and although each possesses peculiar properties, which in the future may be utilized, at present they are but little used.

In conclusion, I beg to call your attention to the wood models on the table, one being representative of aluminium, the other aluminium bronze. The originals of these models are now in the Paris Exposition, each weighing 1,000 pounds. With regard to aluminium bronze, I cannot speak positively, but the block of pure aluminium is undoubtedly the largest casting ever made in this most wonderful metal. I have to thank the Directors of the Aluminium Company,

and especially Mr. Castner, for furnishing me with the interesting series of specimens of raw and manufactured metal for illustrating my discourse.

NOTE.—The exhibit consisted of five to six hundred-weight of aluminium (ninety-eight to ninety-nine per cent.) in various sizes of pigs, ingots, sheet, wire, foil, tubes and rods. Two large blocks, together weighing 116 pounds and testing 99·2 per cent. aluminium, as run direct from the furnace in one charge. Four hundred-weight of aluminium bronzes in pigs, ingots, wire, tubes, sheet and rods. Aluminium iron and steel, ten and twenty per cent. aluminium, one hundred-weight of each in pigs. Sodium in cast bars. Double chloride of aluminium and sodium (crude and purified).

ON THE DILATATION OF COMPRESSED LIQUIDS, PARTICULARLY WATER.*

BY E. H. AMAGAT.

Translated by Chief Engineer ISHERWOOD, U.S.N.

I have investigated the compressibility and the dilatation of the following liquids between zero and 50°, under pressures varying from one atmosphere to 3,000 atmospheres, namely, water, ordinary ether, the methylic, ethylic, propylic and allylic alcohols, acetone, the chloride, bromide and iodide of ethyl, the sulphide of carbon and the chloride of phosphorus.

I shall not be able to give the absolute coefficients of compressibility until I have finished the very difficult work relative to the compressibility of the piezometers, but the coefficients of dilatation under constant pressure can be calculated now, and the following is a summary of the results I have obtained:

---

* *Comptes Rendus*, December 5, 1887, p. 1120.

Putting water, which is an exception, on one side, the coefficient of dilatation of the other liquids diminishes when the pressure upon them increases, the diminution becoming less and less marked as the pressure becomes greater and greater, but under even 3,000 atmospheres it is still very sensible.

Under the atmospheric pressure the coefficient, as is well known, augments with the temperature; this variation diminishes when the pressure increases, until it falls within the limits of error for the experimental conditions employed; for example, in the case of ether under the pressure of 1,000 atmospheres, I have found for mean coefficients between zero and the temperatures of 10°, 20°, 30°, 40° and 50° the following numbers: 0·000891, 0·000890, 0·000905, 0·000897, 0·000909. The other liquids gave analogous results.

My principal object, above all others, was to ascertain the effects of the great pressures. A method was employed up to about 1,200 or 1,500 atmospheres totally different from the apparatus arranged for the highest pressures, and capable of sustaining a pressure which could not be produced in it; the temperature could be raised a number of hundreds of degrees, and, consequently, the critical points of several liquids could be reached.

Atmospheres.	*1.*	*500.*	*1,000.*	*1,500.*	*2,000.*	*2,500.*	*3,000.*
Ether, ...	0·001700	0·001118	0·000909	0·000772	0·000700	0·000631	0·000558
Sulphide of carbon, . . .	0·001212	0·000940	0·000828	0·000735	0·000666	0·000630	0·000581
Alcohol, ...	0·001109	0·000866	0·000730	0·000673	0·000613	0·000556	0·000524
Water.							
From 0° to 10°, ...	0·000012	0·000156	0·000250	0·000315	0·000352	0·000338	0·000383
From 0° to 30°, ...	0·000138	0·000229	0·000302	0·000340	0·000382	0·000420	0·000415
From 0° to 50°, ...	0·000236	0·000295	0·000347	0·000383	0·000408	0·000428	0·000413

The foregoing table contains some of the results determined. It gives the mean coefficients of ether and of sulphide of carbon between zero and 50° and the coefficient of ordinary alcohol between zero and 40° under the different

pressures, increasing by 500 atmospheres, up to 3,000 atmospheres. The coefficients of water under the same pressures are therein given from zero to 10°, to 30° and to 50°, in order to show their variations with the temperature.

We see that at 3,000 atmospheres the coefficient of the ether was reduced to the third of the value it had at the atmospheric pressure.

Comparing the ether and the sulphide of carbon, we see that the ether, which at the pressure of one atmosphere is a great deal more dilatable than the sulphide of carbon, has the same coefficient as the latter at the pressure of 2,500 atmospheres; but at the pressure of 3,000 atmospheres the coefficient of the sulphide of carbon is the greatest, this last coefficient having been lessened about one-half, while that of the ether has been lessened two-thirds.

The case of water is particularly interesting, because we therein see the gradual effacing of the perturbations of the ordinary laws resulting from the fact of the maximum of density.

At first, the coefficient of the water increases very rapidly with the pressure; then, this increase diminishes and disappears towards the pressure of 2,500 atmospheres; we might suppose that under very great pressures, the coefficient would continue to diminish, like that which takes place for the other liquids from the atmospheric pressure.

We will remark, finally, that the increase of the coefficient with the temperature varies considerably under the feeble pressures, diminishing gradually as the pressure rises; at the pressure of 500 atmospheres, the mean coefficient between zero and 50° is still double of that between zero and 10°, but at the pressure of 3,000 atmospheres this increase with the temperature, though distinctly marked, is extremely reduced. At this pressure the water between the experimental limits of temperature, conforms to the ordinary laws of dilatation of the other liquids.

Note by Translator.—In the foregoing article, the temperatures are given for the Centigrade scale. Zero, 10°, 30°, 40°

and 50° on it are, respectively, 32,° 50°, 86°, 104° and 122° on the Fahrenheit scale.

The mean coefficients of dilatation of the different liquids are the mean increase of unit of their volume at the Centigrade zero, in fractions of this unit, due to the experimental increase of temperature above zero, per atmosphere of pressure under the experimental number of atmospheres to which the liquids were subjected.

COMPRESSIBILITY OF THE GASES OXYGEN, HYDROGEN, NITROGEN AND AIR, UP TO THE PRESSURE OF 3,000 ATMOSPHERES.*

By E. H. Amagat.

Translated by Chief Engineer Isherwood, U.S.N.

The experiments on these gases were made according to the method I followed in my previous investigations of the compressibility of liquids within the same limits of pressure; but, in the present case, the difficulty was much greater, owing to the smallness of the volume of the gases when strongly compressed. Nevertheless, after numerous trials, I obtained perfectly regular and concordant results by employing, for the gauging of the platinum wire tubes, the same process of reading by electrical contacts which served afterwards to estimate in the same tubes the successive volumes of the compressed gases. In this manner I obtained for the same gas, with different tubes, graphic curves, which almost absolutely coincided with each other.

My results, given further on, and they are solely the apparent results, differ notably numerically from those obtained by Natterer. The differences within the limits common to our researches are very irregularly distributed, and amount to several hundreds of atmospheres. My experiments for the same reduction of the volume of the

* *Comptes Rendus*, September 17, 1888, p. 522.

gas, give in general much greater pressures than his, but the differences can easily be accounted for by the probable and even inevitable causes of error in the method followed by him.

The following results relate solely to great pressures: the pressures below 1,000 atmospheres will be investigated in part by means of an apparatus permitting the use of temperatures vastly higher than I have been able to command with the apparatus imposed by the very great pressures, and with which I have been able to operate between only 0° C. and 50° C.

The following table gives for the pressures, in the first column, the volumes of the gaseous mass at 15° Centigrade relatively to its volume as unity at the same temperature and under the pressure of one atmosphere:

Pressures in Atmospheres.	Air.	Nitrogen.	Oxygen.	Hydrogen.
750	0·002200	0·002262		. . .
1,000	0·001974	0·002032	0·001735	0·001688
1 500	0·001709	0·001763	0·001492	0·001344
2,000	0·001566	0·001613	0·001373	0·001161
2,500	0·001469	0·001515	0·001294	0·001047
3,000	0·001401	0·001446	0·001235	0·000964

The comparison of the compressibility of strongly compressed gases with each other, and with that of the liquids, is interesting, and to facilitate it I have calculated for differences of 500 atmospheres of pressure the coefficients of compressibility of the gases, as habitually defined for liquids. In the following table are the results obtained:

Limits of Pressure in Atmospheres.	Air.	Nitrogen.	Oxygen.	Hydrogen.
Between 750 and 1,000, . . .	0·000411	0·000407	. . .	. . .
Between 1,000 and 1,500, . . .	0·000268	0·000265	0·000258	0·000408
Between 1,500 and 2,000, . . .	0·000167	0·000170	0·000160	0·000272
Between 2,000 and 2,500, . . .	0·000123	0·000122	0·000115	0·000197
Between 2,500 and 3,000, . . .	0·000093	0·000091	0·000091	0·000158

We see that, under very great pressures, the gases oxygen, nitrogen and air, have nearly the same compres-

sibility; and that it is of the order of magnitude of the compressibility of the liquids; at 3,000 atmospheres it is sensibly equal to that of alcohol under normal pressure.

The compressibility of hydrogen is very much greater—nearly double—and at 3,000 atmospheres it is almost equal to that of ether under normal pressure.

There may be easily foreseen that these compressibilities should, as in the case of the liquids, increase with the temperature, which is shown, as regards hydrogen, by the following table:

Limits of Pressure in Atmospheres.	Coefficients.		
	At Zero.	At 15·4°.	At 47·3°.
Between 1,000 and 1,500,	0·000	0·000408	0·000416
Between 1,500 and 2,000,	0·000263	0·000272	0·000280
Between 2,000 and 2,500,	0·000196	0·000197	0·000208
Between 2,500 and 3,000,	0·000156	0·000158	0·000158

The apparent densities are easily deduced from the first table; and admitting, provisionally, for the compressibility of glass the number generally adopted, we obtain the following results for the pressure of 3,000 atmospheres:

Densities of the Gases under the Pressure of 3,000 Atmospheres, relatively to Water.

	Apparent.	*Real.*
Oxygen,	1·0972	1·1054
Air,	0·8752	0·8817
Nitrogen,	0·8231	0·8293
Hydrogen,	0·0880	0·8887

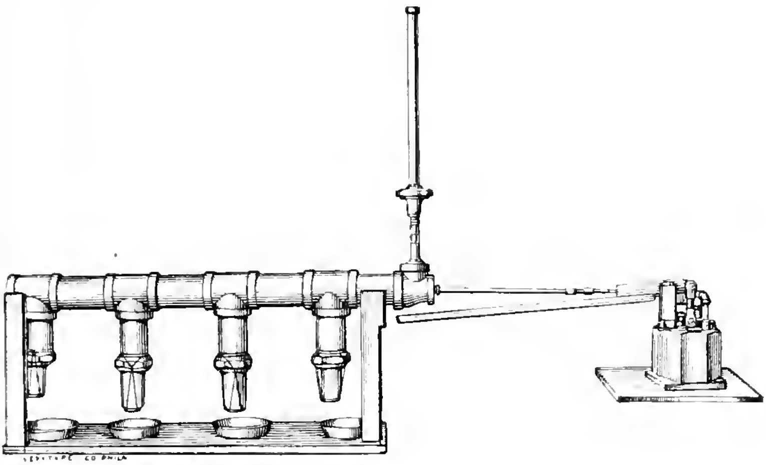
The curves obtained by laying off the pressures as abscissas on an axis, and the products $p\,v$ as corresponding ordinates perpendicular to the axis, are nearly straight lines, but they all have a slight concavity towards the axis. I shall return to this important point as regards the limited volumes after I shall have determined the variation of the volume of the envelopes.

RESULTS OF EXPERIMENTS MADE TO DETERMINE THE PERMEABILITY OF CEMENTS AND CEMENT MORTARS.

By G. W. Hyde and W. J. Smith, University of Pennsylvania.

Condensed by L. M. Haupt.

The apparatus was designed to fulfil the requirements of simplicity, strength, tightness, accuracy, and facility for changing specimens.



It was found to be well adapted to the purpose and consisted of a cylinder composed of wrought-iron three-inch pipes screwed into four cast-iron tees. The far end was closed by a cap, the near end by a tie bushed down to admit the one-fourth-inch feed pipe, on end, and the gauge on top. The specimens to be tested were placed in short six-inch cylinders, three-inch diameter, having a thread cut on the upper end and a perforated cap on the bottom. The hole in the cap was one and one-half inches in diameter. Rubber washers were placed between the caps and samples to be tested, to prevent leakage at the joints. These cylinders containing the specimens were screwed tightly into the tees, and below them

glass beakers were attached by elastic bands to catch the water passing through the cements and mortars.

The water used was first filtered to prevent the choking of the pores by sediment. The pressure was applied by a hand force-pump and maintained throughout the series at 75, 100 and 200 pounds respectively. Four specimens were tested simultaneously.

The accompanying cut will illustrate the simplicity of the apparatus as assembled.

THE SPECIMENS.

Experiments were made on the following brands:

1. Union, furnished by Lesley & Trinkle.
2. Old Newark, by Samuel H. French & Co.
3. Brooks and Shoebridge Portland, Samuel H. French & Co
4. Stettin Portland, Samuel H. French & Co.
5. Anchor Coplay Portland, Samuel H. French & Co.
6. Giant Portland, Lesley & Trinkle.
7. Improved Union, Lesley & Trinkle.
8. Egypt Portland, Lesley & Trinkle.

Each sample was sifted carefully through a sieve having forty meshes to the lineal inch.

The sand was passed through sieves of twenty-five meshes per inch.

The experiments embraced six series:

(*a*) of neat cements after setting seven days.

(*b*) of neat cements after twenty-eight days.

(*c*) of cement mortars, composed of equal parts of cement and sand after seven days.

(*d*) same after twenty-eight days.

(*e*) of cement mortar composed of one part of the former to two of the latter, seven days.

(*f*) same after twenty-eight days.

The specimens were carefully manipulated with just sufficient water to form a thin film when rammed in the mould so as to fill the cylinder to a height of three inches. The samples were allowed to drain for one day, after removing from the water in which they had set, before using.

The following tables give the numerical results of the experiments, showing the amount of percolation in ounces and quarts at the end of each hour under the varying pressures for seven and twenty-eight days, cements and mortars. Where no figures are given, there was no measurable percolation.

TABLE I.—NEAT CEMENTS. SEVEN DAYS.

No. of Specimen.	Variety.	Pressure, 75 Pounds per Sq. In. First Hour.	Second Hour.	Third Hour.	Average per Hour	Pressure, 100 Pounds per Sq. In. First Hour.	Second Hour	Third Hour.	Average per Hour.	Pressure, 200 Pounds per Sq. In. First Hour.	Second Hour.	Third Hour.	Average per Hour.
		ozs.	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*
4	B. & S. Eng. Port.,	...	...	...	...	...	...	...	...	...	...	...	...
24	Improved Union,	...	...	...	...	...	...	...	...				...
15	Egypt Port.,	...	...	...	...	...	...	...	...	...	...	...	...
20	Stettin Port.,	...	...	...	...	...	0·028	0·032	0·020	0·059	0·195	0·135	0·129
54	Old Newark Port.	...	...	...	...	...	0·091	0·227	0·106	0·424	0·525	0·498	0·482
22	Union,	0·044	0·143	0·139	0·108	0·094	0·224	0·169	0·162	0·261	0·361	0·358	0·326
11	Anchor (Coplay),	0·203	0·219	0·216	0·212	0·298	0·306	0·299	0·301	0·426	0·442	0·436	0·434
3	Giant Port.,	0·263	0·299	0·326	0·296	0·233	0·173	0·184	0·197	0·562	0·843	1·224	0·875

TABLE II.—NEAT CEMENTS. TWENTY-EIGHT DAYS.

No. of Specimen.	Variety.	Pressure, 75 Pounds per Sq. In. First Hour	Second Hour.	Third Hour.	Average per Hour.	Pressure, 100 Pounds per Sq. In. First Hour.	Second Hour.	Third Hour.	Average per Hour.	Pressure, 200 Pounds per Sq. In. First Hour.	Second Hour.	Third Hour.	Average per Hour.
		ozs.	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs.*	*ozs*	*ozs.*	*ozs.*	*ozs.*
7	B. & S. Eng. Port.,	...	...	...	...	...	...	...	...	...	...	...	...
23	Improved Union,	...	...	...	...	...	...	...	...	...	...	...	...
14	Egypt Port.,	...	...	...	...	...	...	...	...	...	...	...	...
41	Stettin Port.,	...	...	...	...	...	...	...	...	...	...	...	...
6	Old Newark Port.	...	...	...	...	...	...	...	...	...	...	...	...
21	Union,	...	...	...	...	...	...	...	...	...	...	...	...
2	Giant Port.,	...	...	...	...	...	...	...	...	...	...	...	...
10	Anchor (Coplay),	0·101	0·126	0·103	0·110	0·138	0·186	0·183	0·169	0·446	0·525	0·583	0·518

TABLE III.—MORTARS. SEVEN DAYS.

VARIETY.	Ratio Cement to Sand.	PRESSURE, 75 POUNDS PER SQUARE INCH				PRESSURE, 100 POUNDS PER SQUARE INCH.				PRESSURE, 200 POUNDS PER SQUARE INCH.			
		First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.
		ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.
9. Anchor (Coplay),	1 : 1	4·062	5·155	5·533	4·917	5·926	8·493	8·519	7·646	21·239	21·223	19·522	20·694
49. Stettin Port.,	1 : 2	6·810	6·965	6·9[illegible]1	6·895	10·693	10·916	10·894	10·834	31·342	37·607	34·229	34·392
42. Improved Union,	1 : 1	10·906	11·495	11·411	11·301	17·279	17·5[illegible]3	17·482	17·451	37·690	38·635	38·071	38·468
18. Union,	1 : 1	35·753	42·517	43·448	40·573	53·833	59·909	54·112	55·951	77·374	10[illegible]·[illegible]87	162·941	118·500
17. B & S. Eng. Port.,	1 : 2	50·147	53·254	51·930	51·777	76·004	77·839	77·122	76·988	155·143	150·713	155·583	155·823
35. Giant Port.,	1 : 2	83·056	84·624	84·071	83·919	108·130	109·344	108·912	108·795	137·905	142·606	140·576	140·362
57. Old Newark Port.,	1 : 2	100·294	102·370	102·611	101·758	163·684	166·112	165·722	164·172	. . .	. . .	. . .	. .
13. Egypt Port.,	1 : 2	138·709	139·183	139·845	139·245	169·847	173·357	172·703	171·999	315·355	362·889	317·635	33[illegible]·426

TABLE IV.—MORTARS. TWENTY-EIGHT DAYS.

Variety.	Ratio Cement to Sand.	Pressure, 75 Pounds per Square Inch.				Pressure, 100 Pounds per Square Inch.				Pressure, 200 Pounds per Square Inch.			
		First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.	First Hour.	Second Hour.	Third Hour.	Average per Hour.
		ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.
8. Anchor (Coplay),	1 : 1	1·188	0·978	1·061	1·075	1·706	1·829	1·882	1·805	4·308	4·827	4·743	4·626
16. Improved Union,	1 : 1	2·043	1·922	1·536	1·833	2·382	1·897	2·548	2·275	9·554	9·627	10·667	9·949
19. Union,	1 : 1	5·939	5·685	5·108	5·577	7·621	8·658	8·089	8·122	15·183	14·338	14·378	14·633
45. Stettin,	1 : 2	6·275	6·438	6·349	6·354	9·368	10·319	9·883	9·856	21·514	21·940	21·503	21·652
33. Egypt Port.,	1 : 2	13·214	15·061	14·066	14·113	27·291	28·239	27·814	27·781	52·149	52·711	50·867	51·909
5. Giant Port.,	1 : 2	22·314	23·916	24·015	23·415	35·809	47·746	52·087	45·214	99·290	109·978	99·833	103·033
12. B. & S. Eng. Port.,	1 : 2	35·699	36·055	35·436	35·730	43·744	45·316	44·154	44·404	65·069	65·768	65·342	65·393
39. Old Newark Port.,	1 : 2	109·697	112·831	111·354	111·294	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

TABLE V.—Neat Cements. Seven Days.

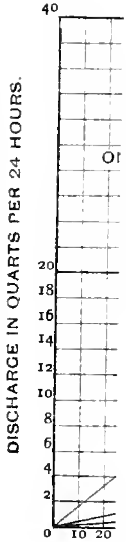
Variety.	Pressure, 75 Pounds Per Sq. In.		Pressure, 100 Pounds Per Sq. In.		Pressure, 200 Pounds Per Sq. In.	
	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.
4. B. & S. Eng. Port., .	. . .	. . .	. . .	. . .	. . .	. . .
24. Improved Union, . .	. . .	. . .	.	. . .	. . .	. . .
15. Egypt Port., ...	. . .	. . .	. . .	. . .	. . .	. . .
20. Stettin Port., . . .	. . .	. . .	0·008	0·006	0·055	0·040
54. Old Newark Port., .	. . .	. . .	0·045	0·032	0·205	0·143
22. Union, ...	0·046	0·033	0·069	0·050	0·134	0·096
11. Anchor (Coplay), .	0·090	0·065	0·128	0·092	0·184	0·132
3. Giant Port., ...	0·126	0·091	0·084	0·060	0·371	0·267

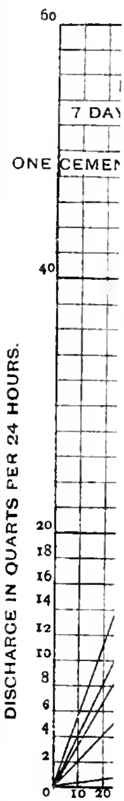
TABLE VI.—Neat Cements. Twenty-eight Days.

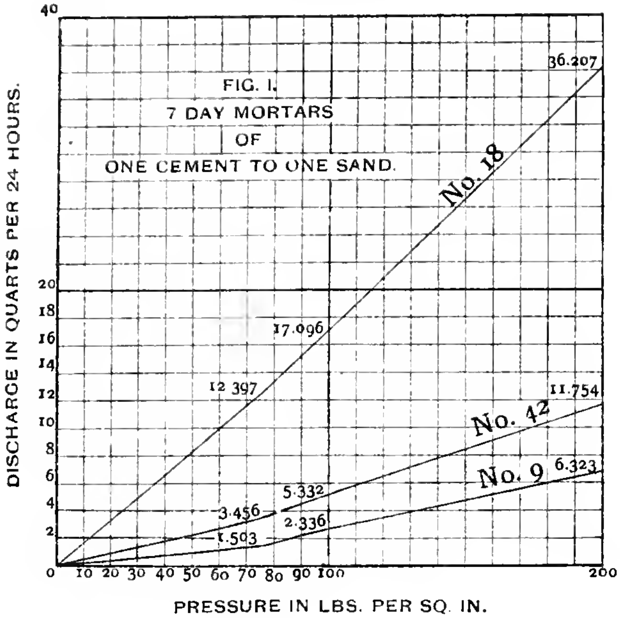
Variety.	Pressure, 75 Pounds Per Sq. In.		Pressure, 100 Pounds Per Sq. In.		Pressure, 200 Pounds Per Sq. In.	
	Ounces Per Surface of 1 Sq. In Per Hour.	Quarts Per Surface of 1 Sq In Per 24 Hours	Ounces Per Surface of 1 Sq. In. Per Hour.	Quarts Per Surface of 1 Sq. In. Per 24 Hours.	Ounces Per Surface of 1 Sq In. Per Hour.	Quarts Per Surface of 1 Sq. In. Per 24 Hours.
7. B. & S. Eng. Port., .	. . .	. . .	. . .	. . .	. . .	. . .
23. Improved Union, .	. .	. . .	. . .	. . .	. . .	. . .
14. Egypt Port., . . .	. . .	. .	. . .	. . .	. . .	. . .
41. Stettin Port., . . .	. . .	. .	. . .	. . .	. . .	. . .
6. Old Newark Port., .	. . .	. . .	. . .	. . .	. . .	. . .
21. Union, ...	. . .	. . .	. . .	. . .	. . .	. . .
2. Giant Port., ...	. . .	. . .	. . .	. . .	. . .	.
10. Anchor (Coplay), .	0·047	0·034	0·072	0·052	0·220	0·158

TABLE VII.—Mortars. Seven Days.

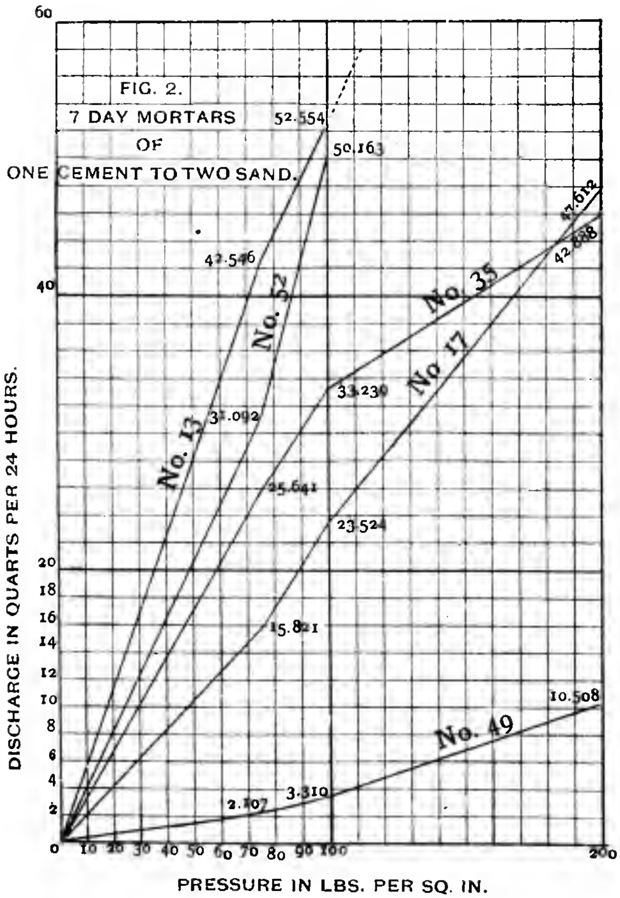
Variety.	Ratio Cement to Sand.	Pressure, 75 Pounds Per Sq. In.		Pressure, 100 Pounds Per Sq. In.		Pressure, 200 Pounds Per Sq. In.	
		Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.
9. Anchor (Coplay), . .	1 : 1	2·087	1·503	3·245	2·336	8·783	6·323
49. Stettin Port., ...	1 : 2	2·926	2·107	4·598	3·310	14·596	10·508
42. Improved Union, . .	1 : 1	4·800	3·456	7·406	5·332	16·326	11·754
18. Union, ...	1 : 1	17·219	12·397	23·746	17·096	50·292	36·207
17. B. & S. Eng. Port., .	1 : 2	21·975	15·821	32·675	23·524	66·133	47·612
35. Giant Port., ...	1 : 2	35·616	25·641	46·169	33·239	59·571	42·888
52. Old Newark Port., .	1 : 2	43·187	31·092	69·676	50·163	. . .	. . .
13. Egypt Port., ...	1 : 2	59·097	42·546	72·998	52·554	140·661	101·268

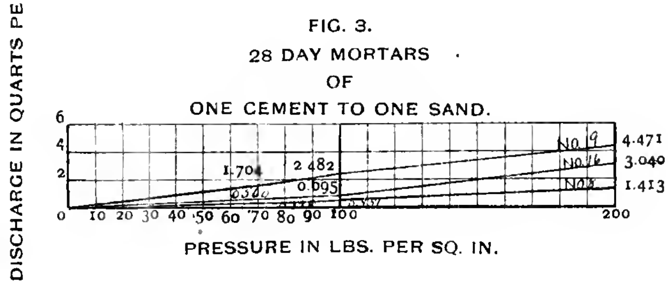

DISCHARGE IN QUARTS PER 24 HOURS.
40
20
18
16
14
12
10
8
6
4
2
0
10
20
ON


DISCHARGE IN QUARTS PER 24 HOURS.
60
7 DAY
ONE CEMEN
40
20
18
16
14
12
10
8
6
4
2
0
10
20



	7 DAYS.	28 DAYS.
EGYPT PORT, ...	No. 13	33
OLD NEWARK PORT,	No 52	39
GIANT PORT, ...	No. 35	5
B. AND S. ENG. PORT,	No. 17	12
UNION, ...	No. 18	19
IMPROVED UNION, . .	No. 42	16
STETIN PORT, . .	No. 49	45
ANCHOR COPLEY, .	No. 9	8





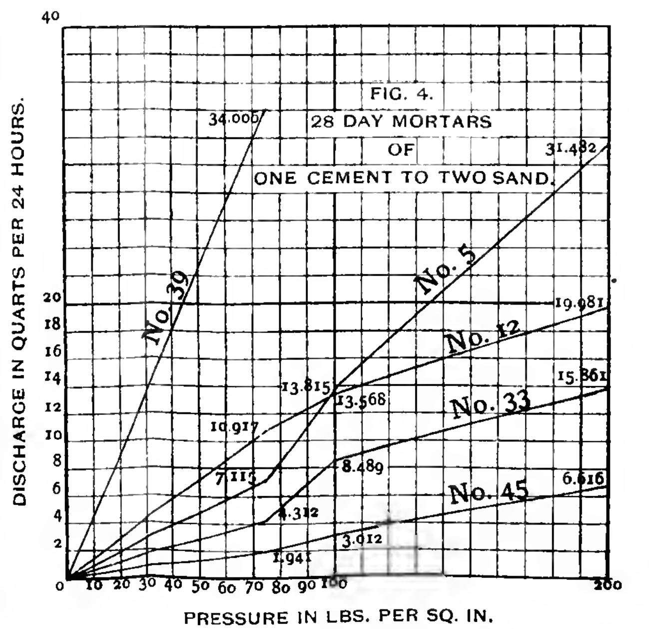


TABLE VIII.—MORTARS. TWENTY-EIGHT DAYS.

Variety.	Ratio Cement to Sand.	Pressure, 75 Pounds Per Sq. In.		Pressure, 100 Pounds Per Sq. In.		Pressure, 200 Pounds Per Sq. In.	
		Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.	Ounces Per Surface of Sq. In. Per Hour.	Quarts Per Surface of Sq. In. Per 24 Hours.
8. Anchor (Coplay),	1 : 1	0·456	0·328	0·766	0·551	1·963	1·413
16. Improved Union,	1 : 1	0·778	0·560	0·966	0·695	4·222	3·040
19. Union,	1 : 1	2·367	1·704	3·447	2·482	6·210	4·471
45. Stettin,	1 : 2	2·696	1·941	4·183	3·012	9·189	6·616
33. Egypt Port.,	1 : 2	5·990	4·312	11·791	8·489	22·031	15·861
5. Giant Port.,	1 : 2	9·938	7·155	19·189	13·815	43·728	31·482
12. B. & S. Eng. Port.,	1 : 2	15·164	10·917	18·846	13·568	27·754	19·981
39. Old Newark,	1 : 2	47·235	34·006	. .	. . .	. .	. . .

ANALYSIS OF CEMENTS BY OLIVER HOUGH, B.S., P.C.

		No. 2.	No. 3.	No. 4.	No. 6.	No. 5.	No. 7.	No. 8.*
Portion Soluble in HCl.	Silica,	13·92	16·88	21·14	20·99	10·18	24·44	15·22
	Alumina,	8·52	6·92	1·02	4·12	4·55	4·69	. . .
	Ferric oxide,	3·20	3·82	2·01	5·18	2·41	3·80	. . .
	Phosphoric acid,	1·82	1·08	. . .	1·17	1·33	0·50	. . .
	Lime,	45·07	58·40	66·04	60·75	59·01†	52·39	55·74
	Magnesia,	7·86	2·06	0·47	0·41	0·60	3·47	. . .
	Alkalies,	1·61	1·03	1·78	1·79	1·61	2·03	. . .
	Calcium Sulphate,	3·21	4·32	3·73	5·02	2·01	3·24	2·57
Insoluble Portion.	Silica,	11·33	4·99	4·36	1·45	13·39	5·17	7·35
	Alumina and ferric oxide,	2·59	0·60	trace	. . .	3·70	trace	1·05
	Oxide of manganese,		trace	. . .	. . .		trace	
	Magnesia,	0·86	0·36	. . .	. . .	0·31	. . .	. . .
	Total,	99·99	100·46	100·55	100·58	100·00	99·73	
	Total silica,	25·25	21·87	25·50	22·44	23·57	29·61	23·37
	Total alumina and ferric oxide,	14·31	11·34	3·03	9·30	10·66	8·49	. . .
	Total magnesia,	8·72	2·42	0·47	0·41	0·91	3·47	. . .

* Uncompleted.

† By difference.

The last four tables were computed from the results as stated in the first four, on the assumption that the percolation varies directly as the diameter and inversely as the thickness. They are reduced to the basis of quarts in twenty-four hours for greater convenience in plotting the curves.

These results show that all cements are not permeable to water, at least for thicknesses of not less than three inches, while the mortars are all permeable; the amount increases with the pressure and decreases with age of specimen, but not in a direct ratio.

Large surfaces, however, are very apt to contain cracks and flaws which greatly increase the permeability. Magnesia is an undesirable constituent, as it causes expansion and ultimate crumbling or flaking. Sulphur will destroy stone or concrete. It is more serious, as it is more intimately mixed. There are colors that contain so much sulphur as to destroy concrete.* The chemical compositions of the cements submitted are given in the above table.

The diagram herewith will give a more comprehensive view of the action of these specimens under pressure. No results are plotted for the non-permeable cements.

For the purpose of comparison it may be well to add that the Board of Experts on the Washington Aqueduct Tunnel in investigating this subject, found that "a good, fair specimen of brick, * * under a pressure of water amounting to eighty pounds per square inch, for one hour, passed 23·4 cubic inches of water." During the second hour it was 21·3 cubic inches. "This is equivalent to 1·75 gallons per square foot of surface per hour, or for the whole surface of the tunnel 27,342,000 gallons per day of twenty-four hours." "Blocks of cement mortar were prepared in the proportion of one part of cement to two of sand," and after setting in water for five weeks one of them gave 2,367·8 cubic inches of water in two and one-half hours under eighty pounds pressure, "equivalent to 73·8 gallons per square foot of surface per hour—very far beyond the amount of percolation given by brick." "The sand here used was not of the very first quality, and the cement brick presented the appearance of great porosity."

Mr. Jas. B. Francis' experiments "showed that about seventeen and one-fourth gallons per square foot passed through a thickness of nearly sixteen inches of cement in

* John C. Goodridge, Jr., 113 East Twenty-fifth Street, New York.

twenty-four hours under a pressure of seventy-seven pounds per square inch." "Mr. Stauffer's experiments, made in the Dorchester Bay Tunnel, serve to throw light on the leakage through brick work. He constructed a bulkhead of brick, laid in cement, four feet thick, in a tunnel 10 x 10 feet. He found that under a pressure of seventy-two pounds per square inch the water percolated through at the rate of 120,000 gallons a day, or 1,200 gallons per square foot." "The experience on the Boston main drainage works proved that it was not practicable to build brick masonry that was water-tight under a pressure of sixty-four pounds per square foot.

"At the new Croton Reservoir, New York, water under thirty-six feet head was found to percolate through twenty-six inches of brickwork and four feet of concrete." *

When water was let into the Vanne Aqueduct in the spring of 1869 the inspector, M. Belgrand, certified that "*Impermeability appeared complete.*"

This conduit is built for miles of béton-aggloméré, composed of sand and cement. The pipe is circular, six and one-half feet in interior diameter, with a thickness of twelve inches at the sides at the water surface, and nine inches at top.

These results show a great range in the amount of percolation, due mainly to the size and character of the ingredients and the manner of mixing.

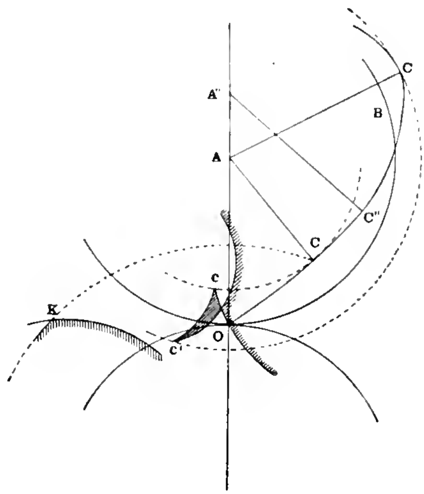
---

* *Vide Report on Washington Aqueduct Tunnel*, p. 21. House of Rep. Fiftieth Congress, Second Sess. Report No. 4,142.

THE CUSPS OF THE GEAR-TOOTH CURVE.

GEORGE B. GRANT, Lexington, Mass.

In designing gear-tooth curves, the flank of a pinion tooth formed on a pitch line that is smaller than a certain limiting size will be found to have a troublesome convolution consisting of two cusps. At each cusp the curve suddenly reverses its direction, and all tooth contact is impracticable beyond the first one.



This happens with any form of tooth curve, although sometimes in disguised form, and the only remedy is to avoid using pitch lines that are small enough to have the defective tooth. If smaller pitch lines must be used, the trouble must be avoided by cutting down the tooth until the cusp is removed.

If the curve is constructed by points, as is always possible, the cusp may be located, but the method is tentative, tedious and inaccurate. The following method will be found to be simple, exact, and of universal application.

In the figure OCC' is the line of action of the tooth system

that is in use, and it is required to locate the cusps of a tooth on the pitch line OB from the centre A.

From the given centre draw an arc Cc internally tangent to the line of action at C, and the first cusp will be normal at c. From the same centre draw an arc $C' c'$ externally tangent to the line of action at C', and the second cusp will be tangent to it at c'.

When constructing a tooth on this pitch line, the flank must end at the first cusp c. Furthermore, the curve of the face of any tooth that is to run with the gear must end at the point K on the arc CK; for, if it is extended further it will interfere with and cut off a part of the working flank of the gear tooth.

To determine the position of the centre of the smallest pitch line that will avoid the cusps altogether, find by trial the required centre A'' from which but one tangent arc can be drawn to the line of centres at C''.

On the VALUE of TECHNICAL TRAINING, and the TEACHING of DRAWING and HAND-WORK in PUBLIC SCHOOLS.

By Edward Combes, C. E.

[*Companion of Most Distinguished Order of St. Michael and St. George, Officer of the Legion of Honor, and President of the Board of Technical Education of New South Wales, Australia.*]

It may be well to introduce this important and interesting paper to American readers by a few words concerning its author and the circumstances under which it was written.

Hon. Edward Combes is an engineer of ability and distinction, among the earliest who sought in the antipodes opportunity to wrest from nature her secrets and her treasures. Going to the Colony of New South Wales as a mining engineer, equipped not only with a technical and practical training as thorough as his native England could afford, but also with a wide and varied polite education, he was

thrown at once into those hardships and dangers, and that necessity of encountering emergencies and overcoming obstacles, which characterized early Australian days. His skill and force of character soon won for him the important position of Government Engineer of Mines; and as his clear judgment became more and more conspicuous in days of turmoil, he was elected member of the Colonial Parliament. He afterwards accepted the important portfolio of Minister of Public Works, at the time when of all others competence and reliability was demanded by reason of the imminence of war between England and Russia, which would mean ruin for the then defenseless city and harbor of Sydney. His name is thoroughly identified with the fortifications and the railway system of the Colony. In 1878 he was chosen as the fittest person to represent his government and country at the Universal Exposition in Paris, where he was made one of the Jury of Award. During that year and part of 1879, Mr. Combes—who received from the British and French governments, in recognition of his ability and services, decorations which he honored in accepting—travelled through the greater part of Europe collecting upon the subject of technical education information intended to shape the coming school system of New South Wales; and visiting this country extended his inquiries with a thoroughness which those who met him and those who have read his admirable and exhaustive report upon the subject* will remember. It was my good fortune to be in almost daily contact with Mr. Combes, during the year or more in which these inquiries were extended in Europe and America, and I take pleasure in testifying to the earnestness and thoroughness with which each system was examined in the most trifling details of its application, and through the widest results which it produced.

Adding to his many attainments that of being a color artist, whose productions have received medals wherever exhibited, and whose ability in this line was recognized by his election as President of the Society of Water-Color

* *Report on Technical Education.* Official Document, Legislative Assembly, New South Wales. Sydney, 1887.

Artists of New South Wales, Mr. Combes can view this question of technical education, and particularly the matter of drawing and handwork, from more sides than any other engineer of my acquaintance; and the eminently practical character of his private and public occupations precludes his entertaining any visionary views upon the subject. As artist and educated gentleman, as engineer having also large mining and manufacturing interests, as legislator and as Minister of the Crown, Mr. Combes has based his opinions upon thorough knowledge of every aspect of the case.

After examining the subject thoroughly, we must conclude with him that to permit any child to grow up with but one side of his nature developed, is a wrong done to him and to society at large. If we do not *put the whole boy to school*, we are lessening his earning powers, adaptability and capacity for happiness and usefulness. If, after knowing the facts in the case, we allow to remain dormant or become dwarfed, any faculty, which has been implanted in the young beings entrusted to us for development, we are unfaithful stewards, incompetent and criminally-negligent guardians, meriting punishment and reproach. ROBERT GRIMSHAW.

No apology is needed for the subject of this paper. The education of the artisan and mechanic has occupied the attention of the greatest statesmen, as well as that of the most distinguished and eminent educationalists, throughout the whole of the civilized world, for a considerable number of years. Inquiries have been made by boards, commissions and committees appointed by nearly all the leading governments of Europe and America, as to the advisability of technical teaching, and in every case the conclusion arrived at has invariably been the same, viz: that its importance and utility could not be overrated and that it was the absolute duty of their respective governments to provide such instruction in the best possible manner. This has been carried out with greater or less good results; and my object is to bring before you, in as concise a manner as

practicable, the existing facilities, in actual operation, for imparting this class of instruction, and the general character of the primary education given in different countries with regard to its connection with the technical training necessary to afford the young such opportunities of acquiring that characteristic knowledge suited to the works and manufactures belonging to the particular district in which the school is situated.

While no real difference has existed among the advocates of technical teaching as to its general advisability, there have been a variety of opinions as to the manner or method of imparting it. One great question is with reference to apprenticeship schools. It is contended on the one hand that the old system of apprenticeship has completely broken down, and that consequently it behooves the state or the municipal government to teach the various trades in schools instituted for that special purpose. On the other hand it is stated that these trade schools are objectionable, on account of an expense not warranted by the results, and, moreover, that properly-equipped technical schools for every trade would practically be an impossibility. They also argue that such schools are not thoroughly effective, as improved methods and machinery are being daily discovered and applied, and consequently, that such schools could never keep pace with the factory, however perfectly the school might have been established in the first place. That the work accomplished would not be real, but of a very mediocre class, and that for want of association with real workmen, the school-taught artisan would be unable to commence as a skilled workman. There is much to be said on both sides, for while there can be no doubt as to the utility of apprenticeship schools for turning out scientific and highly-skilled workmen, eminently fitted for foremen, managers or proprietors of industrial works, the cost of training in these institutions is too great altogether, for the system to be applied to the masses. There can be no doubt that there is room for many modifications of the systems, and that more economical arrangements will be made in the future development of these establishments, which are numerous in Europe and con-

stantly increasing. They have proved their value over and over again in forming the most thoroughly trained artisans in most kinds of skilled labor, both in the practice of the art and in the knowledge of that science which underlies it. I may mention here that the success which has attended the industrial schools, established by law in France, Belgium, Germany and Switzerland, to give technical instruction to the masses, who have to live by the work of their brains as transmitted through the work of their hands, has been simply marvellous. It has been positively proved that the technical or practical work never injuriously affects the theoretical studies, but that, on the contrary, the manual work acts as a stimulus in the subjects of descriptive geometry and industrial drawing. This affords independent and direct testimony that the mental and physical powers are in direct accord, and can be simultaneously or concurrently educated with advantage to both.

But whatever may be the differences of opinion with reference to apprenticeship schools or manual training, there are none existing as regards the necessity of teaching drawing, which is the true and solid foundation of technical training. Ten years ago I advocated the simple principle that drawing should be taught in all the elementary schools. In my opinion a child should commence drawing, when learning his alphabet: to learn the name of a letter, and at the same time to imitate its shape from a model, enables the child to learn reading, writing and drawing, at one and the same time. The child learns far more quickly than he possibly could if he were taught separately, for the one helps the other; the eye and hand are brought into unison from the first, and once this is firmly established everything else comes easy.

The importance of drawing in industrial education cannot be overrated. It is the foundation of all the constructive arts. No industries can wholly dispense with it, and its exercise instructs the eye and hand to travel together. It is an essential aid to every class of artisans, while it instructs and improves both mind and body in its imitation of nature. It has often been called a universal language common to

all people of every nation. It is therefore clear that it should be commenced at the very earliest period, so that from the beginning of the child's tuition his eye and hand should thoroughly understand each other.

I say that no difference of opinion exists as to the necessity of teaching drawing at the earliest age, and from my own knowledge, I can state that a child learning his letters in the way I have above stated, on the three subjects at the same time, certainly learns to read and write more quickly than he otherwise would. I am happy to say that drawing has been made a branch of primary education in almost every system of elementary public instruction, and is now considered as necessary to a child's education as writing. It is no longer optional, but a required study. Its adoption is no longer an experiment, but an undoubted established fact. This must be honestly considered and attended to by the teachers of state schools. Many public school-teachers have never had the opportunities that are now given in normal schools and training colleges, to acquire that freedom of hand so necessary to the skilful artist, therefore they should take every opportunity to improve themselves in free-hand drawing. I find, wherever I have been, that generally the teachers are making the most strenuous efforts to carry out the instructions of the school boards, and every year will make a marked difference. The teachers have themselves become convinced of the necessity of teaching drawing from the earliest age, and consequently energetically endeavor to qualify themselves to impart the required instruction. At the present moment a great movement is going forward. A school training is required that will give better results in the every-day work of life than have hitherto existed. Drawing must be taught, and this must be done honestly, and not in any half-souled manner. The teacher must throw himself, or herself, into the subject enthusiastically, and then proportionate progress will be made. It must never be forgotten that the practice of drawing renders the pupil more apt, and better able to receive any subsequent industrial training, no matter in what branch of applied art, or whatever may be the industrial occupation.

It should constantly be borne in mind that the shorter time required to reach the position of a skilled workman, is a direct money gain to the State, fully sufficient to compensate the cost of the education. Froebel says that "drawing, painting, and modelling must necessarily be considered as a part of the general comprehensive education and training of man. They must be early treated as actual objects of the earnest school, and not be exposed to an accidental, worthless and fruitless and wanton arbitrariness; neither with the view that each scholar becomes an artist in some kind of art, and far less with the view that each scholar will be an artist in all branches of art, both of which nullify themselves; but with the definite view that each man may be raised to the point of developing his nature faithfully, completely, and on all sides; that he can raise himself to the point of recognizing the all-sided and all-powerful nature of man; but especially, as has been already stated, that each man understands how to perceive and to value the results of genuine art."

In bringing up a child in the knowledge of what is good and true and beautiful, we find that the study of drawing has immense advantages directly valuable as educational influences, and where the greatest attention has been paid to this principle, there also we find the greatest practical skill. The educating power possessed by elementary drawing is not doubted, and the great accuracy which drawing requires affords the best possible practice to the eye and hand, while of great value in training the mind to be observant, judicious and active. Imagination precedes reasoning, therefore the imagination should be cultured in primary education in such a way as to occupy a prominent place. We know that nothing is more attractive to the imagination than the beautiful. The sense of the beautiful is called *taste*, and should be accorded a first place in every system of instruction, more especially in primary instruction, and in the teaching of poetry and art; for, if education in the first place proceeds by images and realities, we should make use of them, by making them the vehicles of teaching the sublime and the beautiful.

It has been well said that beauty is another word for education, and the connection of culture in the beautiful, with culture in morals, is fully apparent. In the recognition and the feeling, the loving and doing of the beautiful, coarseness and vulgarity, and tendencies towards debasing and sensual enjoyments find a countervailing power. The virtues especially developed by the study of drawing are persevering industry, love of unobtrusive right action, order, decency and purity. Goethe says: "The importance of instruction in drawing as a part of education will best appear when we consider that by means of that acquirement we gain an increase of beautiful and noble pleasures derived from the external world. The whole realm of form and color opens to man; he acquires a new mental organ; he receives the most delightful ideas and learns to recognize, to respect, to love and to enjoy the beauties of nature. Nothing gives the same amount of true happiness as art. Why, therefore, should not the masses be taught to obtain the salutary influence which it gives to those who have cultured tastes and a love for the beautiful, and who can appreciate to the utmost, by sight and hearing, correct proportions and divine harmonies." The man who has during a certain number of hours of the day to labor to gain his livelihood would surely gain the greatest consolation and solace in being able to see and understand the beauties of nature, and endeavor, by his own hand, to reproduce what he sees in clay or in colors, or simply in black and white by his pencil. Impressions that we obtain by our sense of sight imprint themselves upon the brain, and where preconceived ideas are wrong, they are instantly changed for our benefit by the correct judgment of the eye. It is, therefore, universally admitted that drawing should occupy a most important position in primary instruction, and that, when taught as it should be, it not only gives the facility in a greater or less degree to represent the various forms which occur in almost all trades and professions, besides being of inestimable value in the work of ordinary life, but it gives to all that correctness of eye and taste without which the true sense of the beautiful can never be thoroughly understood. In archi-

tecture, as in sculpture and painting, drawing is at once the instrument and the language. "To know how to draw," says Michael Angelo, "is to have the compass in the eye." The geometrician wants the compass in the hand, but the designer and painter want it in the eye. In the first place, mental calculation is required, while in the second there is an immediate intuition in a single glance. It is usual to speak of different systems of art education as the French, South Kensington, German or American methods, whereas in none of these countries is there any hard and fast, or even any comprehensive system of giving instruction in art for the public schools. As a matter of fact there is no absolutely national system of art education. When any of these so-called systems are taught, they are found to be the method of some talented teacher who personally gives instruction and advice to each individual pupil. It will be impossible here to describe the various plans adopted by different teachers, but I may mention that the one great common difficulty is in qualifying the regular school-teacher to impart art instruction, and the only practical way out of the difficulty is to encourage teachers to attend training schools, whose classes shall be open to teachers during the ordinary vacations. I am aware that this has been partially done here, as well as in many localities in Europe, with excellent results. It stands to reason that once the ordinary school-teacher, who has the confidence of his pupils, is capable of cultivating a perception and love of the beautiful in their minds by means of drawing, half the work will be accomplished. To learn to draw will be no longer an arduous task, but a pleasurable recreation in which the children will delight.

In Germany the teaching of drawing has undergone considerable change within the last few years, chiefly owing to the admirable teaching of Mr. Jessen. His success became most remarkable. Mr. Jessen was a civil engineer of Hamburg, where he established, at his own expense, a special school wherein to experiment with a method he had conceived for teaching drawing. His first trials were so extraordinarily successful that the municipal authorities of

Hamburg took the school into their own hands and voted for its maintenance £3,500 ($17,500) annually. This went on until 1875, when, on account of the ever-increasing number of the pupils, the municipality erected a new school, to which a museum was attached, costing £150,000 ($750,000), and at the present time there are over 2,000 pupils receiving instruction. Mr. Jessen has been appointed the art director of all the municipal schools, so that his method of teaching might be generally adopted.

This method appears to consist less in the innovation of any new scientific means of teaching the principles of drawing, than in giving the pupil, individually, that particular and special instruction which the necessity of his trade or profession requires. The time of study is not fixed, and the pupils stay at school three, four or five years, according to their aptitude in acquiring the necessary instruction. Often the very intelligent ones obtain proficiency in two years. All the courses take place in the evening. The first half of the first year is exclusively consecrated to the study of the primary elements of drawing, such as are generally taught in all the schools; but drawing from the flat is absolutely forbidden. Every lesson is drawn from an object. In the second half of the year professional drawing is commenced, and as soon as the pupil really knows how to draw, his work is chiefly confined to models which apply to his particular profession. In the following years the professional work and general artistic work are about equally divided, and one day in the week the work is exclusively professional, under the direction of a working foreman. This class is often held in private workshops, to teach the application of the general principles learnt at school. Private workshops had to be used, as, at the time of my visit, the government had not organized any manual professional schools. The great singularity of Mr. Jessen's method is that the pupils do not receive their instruction in class, but that each one, individually, receives a personal intimate instruction, varied in accordance with his temperament and aptitudes. The professor is always in attendance in the school, where he is continually engaged inspecting the work of the pupils,

reasoning with them and giving them judicious counsel; in short, he follows step by step the work of each student placed under his direction.

It is this individual instruction that causes the great success of Mr. Jessen's method. It enables the teacher to take into particular consideration the capacity of each particular pupil. This is a most weighty circumstance, because, in drawing solid objects, the clearness and liveliness of the perceptive powers, the accuracy of the eye, and dexterity of hand must be brought out. These qualities are very important, and are found to differ exceedingly in different individuals. By *individual* treatment, those in every way naturally gifted need not be held back, while the weakest need not be dragged along in order that the medium, forming the majority, should not suffer.

The question as to the best method of giving a technical education to the youth of a country, is the great problem of the age. Upon its proper solution the prosperity of a country as regards its agricultural, industrial and commercial relations may depend. It concerns the working population, the masses of the people, over whom it is the duty of the government to watch with an ever-increasing solicitude. It is exactly this class of instruction which enables the future man or woman to earn a living, and by producing a good class of workmen to place the country in the best industrial position. The great desire of all nations is to produce work by which their respective populations may live, and this desire extends itself year by year in direct proportion to the relative increase of population. It is not only a social but a political question of the highest importance. To place the people of any country in a position to successfully compete with the rest of the world, is the object of all who desire their country's good. The imperative necessity of comparatively placing the people in this position is self-evident, and no one dares to question its practical utility. The matter to be considered is, how to do this in the most practical and effective manner.

The old system of making workmen was by the process of apprenticeship. This was the only road to learn a trade.

The apprentice paid a fee for instruction and received his board and lodging as an equivalent for his work. He was of the family of his master, his friend, and often became his son-in-law. There was every inducement for a master to teach his apprentice, accordingly apprentices were carefully instructed, and there existed a sufficiency of good artificers in proportion to the demand for their work. Now, however, this is altogether changed. The invention of machinery and special tools has destroyed the old workshop and diminished small factories, and the industrial system of the country has been revolutionized and reconstructed. This reconstruction has its good as well as its bad side. Manufactured articles of all kinds are incredibly cheaper than they used to be, and there is for all who choose a greater chance to enter the class of skilled artisans. On the other hand, the mechanic is kept week after week and year after year at one particular branch of the trade, such is the necessary result of a division of labor. There can be no doubt that this monotonous employment and specialization of labor tends to the degradation of the workman and to a diminution of the art-value of his work. The manner, therefore, of educating young artisans daily becomes more important, and an opinion is steadily growing up that our elementary training, whether for rich or poor, is still exceedingly incomplete, and will never become fitted to the wants of the time until it has undergone some radical modifications, and I thoroughly believe that these will take the form of manual training.

If we divide the future occupations of the youth of all countries into agricultural pursuits, industrial production and manufactures, distribution and commerce, together with the learned professions, we find that the teaching is not in accordance with this division, but that in the provisions made by the public or state schools, it would seem that all our young men were to become parsons, clerks and lawyers. There is nothing industrial in the curriculum or anything really adapted to the manufacturing requirements of the country. It indicates that educationists have begun at the wrong end. That the culture of the masses should

precede their industry, whereas it has been universally conceded that the ornamental should wait upon the useful. It remains, therefore, to instruct the masses in such a manner that, while giving them their ordinary tuition in reading, writing and arithmetic, they may learn to use their hands as well as their heads.

The question as to the possibility of organizing workshops in primary schools has been often considered. The decision arrived at has been generally in favor of the principle, but that the practical teaching of different trades would be next to an impossibility. To carry out a system of manual training in primary schools, it is necessary to generalize and to teach that class of work which is common to all handcrafts, and useful to everyone whatever may be his social condition; work just sufficient to develop manual dexterity, and which will also serve for purposes of recreation. This is not at all theoretical. The system has been applied in hundreds of cases, and given results eminently satisfactory.

The work adopted as the most convenient is that which is the most simple in its character; the easiest class of carpentry and wood turning. With boys there seems to be an innate longing to use carpenter's tools, and this is quite sufficient in the first instance to set in motion the constructive faculties, and to develop manual dexterity. Besides, these elementary exercises do not require large workshops or expensive tools, but can be taught in the play sheds of ordinary primary schools. In France, handwork in schools is now made compulsory.

I must, however, find space for noticing what has been done of late in Sweden, more especially in the training of the ordinary school-teacher, both male and female, so that they may be qualified to impart the knowledge of manual work to their pupils. In the Swedish language this handwork is called *slöjd*, a word which has no exact equivalent in the English language.* It is an old national word, coming from an epoch when nothing but hand tools were used. It

* Perhaps our word "sleight" still bears about the same meaning. R.G.

does not mean any handicraft, but implies a general sense of dexterity and cleverness. Thus, speaking of a farm laborer as a *slöjdare* means, that while he is simply a laborer, he is a handy man and able to use and repair the common tools and implements in use on the farm.

This simple work was originally taught to children by their parents, for it was customary with the peasant to make and repair any furniture or tools required by the family. This was generally done during the long winter evenings. When factories sprung up, making cheap articles of iron and ware to replace those wooden utensils, the desire and the aptitude for making them at home were by degrees lessened and, indeed, almost altogether destroyed. The workman degenerated to such an extent that the government instituted an inquiry into the cause, when it was found that out of twenty-four districts only five retained anything like the habitude and custom of this cottage labor. The laborer was no longer a *slöjdare*, and his production having ceased, the country lost a considerable source of wealth. It was thereupon determined that this manual training should be taught in all the primary schools.

The great difficulty was the teacher. It was necessary to train them, and here a patriotic gentleman, named Abrahamson, came forward, and not only established a normal school for the purpose, but duly endowed it, placing it under the direction of his son-in-law, M. Solomon, who was also one of the first and most fervent propagators of manual work in primary schools. In conjunction with the founder, this gentleman has carried forward the grand work with the greatest enthusiasm, and their wise lessons cannot possibly be studied without appreciating the important results that have been achieved by the teaching of handwork in primary schools.

It has been directly and definitely proved that this manual teaching must not be confided to artisans without any knowledge of pedagogy, therefore it goes without saying that in future handwork should be taught in all normal schools, and no appointment of teacher made to any school, unless he or she be duly qualified to impart this knowledge.

When manual work is universally taught in all primary schools, how much more efficient will become the professional and apprenticeship schools. The pupils having already gained that dexterity so requisite to all handicrafts. Moreover, the habile workman will be made in less time. He will be as clever and experienced at 18 years of age as otherwise he would have been at 21; thus three years will have been saved, and allowing a man able to work at his trade thirty years, there will be an increase of one-third in the producing power of the state, which, in a money value, would more than compensate the government for any sum it might expend in the complete organization and perfection of a thorough system of technical training.

The training now instituted in America, Belgium, England, France, Germany, Holland, Russia, Switzerland and many other countries is chiefly of a secondary character, the apprenticeship and professional schools are exceedingly numerous and constantly increasing. Time will not permit any detailed description of these schools, of which, perhaps, the Ecole Diderot, of the Boulevard la Villette, in Paris, is the best typical form, and young men leaving it readily obtain wages of from four to seven francs a day.

The opportunities and facilities for the acquisition of technical knowledge have been far greater in France than in any other part of the civilized world. In France, every instruction can be easily obtained. From the National School of the Fine Arts to the rudimentary class at the primary school, all is free, and throughout the whole of the country there are departmental schools, both in the day-time and during the evening, giving instruction gratuitously in every branch of art and design, and, as I have mentioned before, manual training is compulsory. This explains at once the reason that France exports millions, nay, hundreds of millions, of value in commodities, of which the chief value lies in the labor consumed in making the article, and every nation contributes to her prosperity in purchasing these commodities. The immense sums spent by the French government in providing the technical instruction for the production of workmen capable of this class of work,

are amply compensated by the wealth obtained through the contributions of capital by the entire civilized world.

With the progress and development of a nation, there ever follows a fiercer and fiercer competition in matters pertaining to labor. It therefore follows that for any nation to hold its own, the highest technical skill will be necessary. To obtain this skill the rising generation must be instructed, not only in the ordinary subjects of education, but also in the use of simple tools, so that manual dexterity may be obtained at the earliest possible period. The education that will compass this must necessarily bring about another desideratum. Children who have been taught the use of tools will not in after life look down upon those who labor with their hands. They will have been taught through the equality that exists in the school and as bench-mates in the work shop, that all labor is honorable, and that good fellowship should always exist between them as fellowmen, a feeling which cannot but conduce to the general diffusion of happiness, and consequently to the good of the commonwealth.

HARBOR BAR IMPROVEMENTS.

By L. D'Auria.

In an article published in the Franklin Institute Journal for July, 1889, under the above head, Prof. L. M. Haupt, C.E., shows in a very brilliant manner the momentous importance of removing bars which are formed by the forces of nature at the entrances of harbors, a fact, which has always been recognized by commercial nations, but believed by Professor Haupt to be disregarded by the Government of the United States, because this Government has not yet adopted his plan for removing such bars.

The professor wants the abolition of parallel or nearly parallel jetties as means to improve harbor entrances, and he quotes the highest English authorities on the subject. These authorities seem to discourage such jetties, but, as yet, do not feel competent to suggest new means; and it is

difficult to understand why they have not yet adopted those proposed by Professor Haupt, as set forth in his pamphlet, entitled: *The Physical Phenomena of Harbor Entrances. Their Causes and Remedies. Results of Present Methods of Improvement*, which was crowned by the American Philosophical Society, December 16, 1887, with the award of the Magellanic Premium.

In this pamphlet, right on the first page, the author says:

"Before any radical or permanent improvement can be effected, it is necessary that the forces operating at any point should be fully understood, and, so far as possible, be measured."

Let us see how Professor Haupt understands these forces, and whether he has made any attempt to measure them.

He claims (page 20, above-quoted pamphlet):

"The enunciation of the principle that the cause of the angular movement of the ebb stream after egress is due to the general form of the exterior coast line, which causes a racing of the tidal crests, from the outer capes toward the bight of the bay, and that the *flood components thus generated are the principal forces* which build the bars and shift the inlets. This incessant semi-diurnal action of the flood is the *controlling element* in the forces affecting the magnitude and position of the bar. Storms and winds may modify and shift the deposits, but eventually the flood re-establishes the original conditions." (The italics are his.)

As the crest of a tidal wave moves by propagation, *the racing of the tidal crests, from the outer capes towards the bight of the bay*, cannot mean anything else but the propagation of two tidal waves in such directions. In fact they must be the waves which produce what, on page 7, he calls *flood resultants.*

On page 8, he says:

"It now remains to determine why this resultant should be sometimes from the northeast, and at other times from the southeast. This leads at once to an examination of the phenomena attending the approach of the tidal wave and

the position of the cotidal lines with reference to the coast line. For this purpose there are available the general cotidal maps of Professor Guyot, and the more detailed maps of Professor Bache, accompanied by the tide tables of the Atlantic coast, as contained in the *United States Coast Survey Report.* Meagre as these data are, they are yet sufficiently abundant to confirm the existence of the alleged resultant movements, and to verify in the most satisfactory manner the reliability of this method of determining the forces by their effects."

This is certainly a very startling conclusion reached from *the position of the cotidal lines with reference to the coast line,* for Professor Bache himself in commenting about such lines, says:

"The chart shows how simple the system of cotidal lines is in the three bays running nearly parallel to the shores" (*Coast Survey Rep.*, 1857, p. 346). In other words, we know that the tidal wave is propagated in a direction normal to the coast line and not parallel to it, as Professor Haupt concludes. But the professor in a correspondence on the subject says:

"This crest line cannot be supposed to have sufficient prescience to advance or retard itself at a considerable distance from shore, preparatory to rolling up on the beach normally."

Does he understand the meaning of the cotidal lines? It seems not; and yet Professor Bache says: "How simple the system of cotidal lines is." If Professor Bache is that authority on the subject of tides, which scientists and investigators consider him to be, certainly Professor Haupt needs schooling on this subject. The evidences are that Professor Haupt has an altogether erroneous idea of the tidal wave, for in the above quoted correspondence speaking of the tidal wave he says:

"It meets an obstruction, its oscillations are restricted by the shelving beach, the wave is tripped and broken, and the surf churns up the sand."

Here Professor Haupt degrades the *tidal wave* to the rank of a simple *breaker.* Then he goes on to say:

"If the wave breaks normally the sand is merely rolled up and down the scarp of the beach, but if obliquely it is turned over and carried to a more remote part of the shore. The action is similar to that of an auger."

Here Professor Haupt evidently repudiates his idea, originally stated, of a *littoral movement of water* in the direction of the shores. He no longer doubts the *prescience* exhibited by the tidal wave in preparing itself to roll normally upon the shore: he has been made to understand differently the forces which, he says, *should be fully understood before any radical or permanent improvement can be effected;* all this in the hope that the tidal wave will be capable of rolling sand up and down the beach in a zig-zag manner.

In the light of the foregoing criticisms, it is difficult to appreciate wherein Professor Haupt is entitled to "*the merit of having not only clearly perceived and distinctly enunciated the laws concerned as the basis of his argument, but also to that of proffering, in connection with the statement of those laws, an invention contributive to the interests of navigation,*" etc. (see *Report of Committee*, Ameriean Philosophical Society).

However, as the professor tells us that the *forces operating at any point should be fully understood, and, so far as possible, be measured*, we thought to measure them for him, having already assisted him in understanding them through a correspondence deposited with the Secretary of the FRANKLIN INSTITUTE already cited above, and which is accessible to the reader on application.

The method employed for such measurement is as follows:

Assuming a rise and fall of tide of four feet, the mean velocity of the flood current in a direction nearly normal to the shore, at say 100 feet from it, would, in ten feet mean depth of water, be $100 \times 4 \div 10 = 40$ feet in about six hours; or nearly seven feet per hour. Make it ten feet per hour. Then, since it is known that it takes a mean velocity of one-half mile, or about 2,500 feet per hour to just raise sand from the bottom (see *Trautwine*, edition of 1885, p. 270), and according to Professor Haupt's own statement the transporting power is proportional to the sixth power of the

velocity, a mean velocity of ten feet per hour would possess a transporting power equal to $\frac{1}{244,000,000,000,000}$ of that required to begin the transportation of sand.

When such utter impotency of the flood tide to build bars was shown to the professor, we expected that he would become converted to the fact that only wind waves or breakers can do such work. But no, he sprang up from this, and in his bewilderment he appealed for help to the keepers of life-saving stations through the Hydrographic Office; trying to establish, no more the auger-like action of the tide which he thought to have discovered, but an actual littoral current produced by the tide, of such power as to drag ships on the bottom of the ocean! Like a modern Faust, he seems to have cursed science and given himself to the *world*. We see him again in his last article, *Harbor Bar Improvements*, upbraiding *the people of the State of Texas for appealing urgently for the rapid completion of the project* at Galveston Bay, which, according to his ideas, *will violate the fundamental requirements of the greatest freedom of influx to the flood tide that there may be a full prism for ebb scour.* Evidently Professor Haupt has yet to learn the relation existing between flood and ebb at the entrance of a tidal basin as that of Galveston Bay, and the people of the State of Texas may well be congratulated for not sharing the professor's views.

Let h_0 represent the average depth of the entrance to a large tidal basin at mid-tide; x, the height of tide above h_0 at any instant of time; y, the corresponding mean width of the entrance at such time; and g, the acceleration of gravity. Then the cross-section at any time will be

$$\Omega = y\,(h_0 + x) = y h_0 + y\,x\,;$$

and the mean velocity through this cross-section can be computed by considering the water in the first part, $y\,h_0$ to remain stagnant, while the water in the second part, $y\,x$, moves with the velocity of propagation of the wave which is known to be expressed by $\sqrt{g\,H}$, in which H represents the mean depth at high water for the whole basin.

Then the mean velocity through the whole cross-section Ω will be:

$$u = \frac{x y \sqrt{gH}}{y (h_0 u + x)}$$

or simply

$$u = \frac{x \sqrt{gH}}{h_0 + x}$$

This formula shows very clearly that the mean velocity through the entrance of a large tidal basin is independent of the width. It shows also that at high water the velocity is a maximum, and at mid-tide it becomes zero, which accords very well with observations taken at the entrance of large tidal basins during flood tide. When x becomes negative, we have the mean velocity of the ebb current, which is also zero at mid-tide, and a maximum at low tide.

Applying our formula to the case of Galveston Bay, Texas, it can be seen that the jettied channel will, in ordinary circumstances, be scoured with at least the same velocity as now exists through the entrance to such bay, although the tidal volume is diminished considerably.

We cannot see, therefore, any violation of *the fundamental requirements of the greatest freedom of influx to the flood tide that there may be a full prism for the ebb scour*, in the case of the project of Galveston Bay, so severely criticized by Professor Haupt, and we once more congratulate the people of the State of Texas for urging the completion of such project.

On CHENOWETH'S ELECTRIC CONDUITS.

[*Report of the Committee on Science and the Arts.*]

[No. 1419.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 29, 1889.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred for examination,

THE CHENOWETH ELECTRIC CONDUITS,

Report that: The invention belongs to that class of conduits in which the material of the conduit is packed while in a plastic condition, around one or more cylindrical cores, which are removed after the plastic material has hardened. The essential part of the invention is the nature of this removable core, which enables it to be withdrawn in long lengths. This core consists of a ribbon of galvanized iron, one inch wide and of a thickness equal to No. 27 gauge, which is wound spirally, forming a tube. This spiral tube is rendered rigid, either by being wound around a split wooden core, or by having paper glued around the outside. The plastic material is packed around these tubes and after it has set the tube is removed by pulling out this spiral band. When paper has been used to hold the spiral together, it readily tears, allowing the band to be removed. When wooden cores have been used, they are first withdrawn, after which the spiral band is readily pulled out.

Among the details of the system are the following:

When paper is used to unite the spiral into a rigid tube, the ribbon is first wound spirally on a mandrel, then covered with paper, which is glued fast to the outside of this spiral, and the whole covered with a water-proof varnish. The mandrel is then removed, leaving a thin tube, which appears to be quite rigid and capable of withstanding the pressure

due to the packing of the plastic cement of the conduit around it. These are laid in lengths and held in position while the cement for the conduit is packed around them. The ends of the one spiral ribbon are fastened to the beginning of the next, by a swivel joint. After a few days, when the cement has hardened, the spiral ribbon is pulled out at one of the manholes, tearing and thus removing the paper around it. It is claimed that long lengths of this spiral tube can be thus removed.

When this spiral tube is wound over a wooden core, this core is made in two semi-cylindrical halves, separated by a thin iron strip. The outside is painted with a mixture of clay, powdered soapstone and water. These are laid in lengths of fourteen to twenty feet, and after the cement is packed around them the wooden cores are withdrawn, after pulling out the strip of iron separating them. This leaves the spiral tube, which remains until the cement has hardened and is then withdrawn in long lengths.

The inventor claims that continuous lengths of 400 feet of spiral tube can thus be withdrawn. For removing this ribbon, the inventor states that he has a peculiarly constructed reel, by means of which the ribbon can be pulled out, wound up and untwisted in one operation.

For the material used for the conduits, the inventor prefers a mixture of one part of hydraulic cement and two parts of sand. The costs are given by the inventor as follows:

"The cost of constructing ducts by this method is narrowed down to the winding of the ribbon on the mandrel, the labor of removing the mandrels in the trench, of removing the ribbon from the duct and rewinding the ribbon on the bobbins. And as each part of the core is preserved and used an indefinite number of times, the cost of the core is charged to the cost of the plant. The winding of the ribbon is done on the spot as fast as wanted. The cost of drawing out the ribbon and rewinding on bobbins, using an ingenious device that removes all twists, is about one mill per foot. A duct, four inches in diameter, made of concrete, in the proportion of one of cement to two

of sand, can be made for six cents per foot, including entire cost, exclusive of excavation, manholes and openings."

The inventor claims that the advantages of the paper-covered tube is convenience, the cost being about the same.

The inventor gives the following comparative costs of materials for three forms of conduits. The estimate is for a conduit of four ducts, four inches in diameter, one foot long. For creosoted wood, six cents per foot per duct; for iron pipe, encased in concrete, eighteen cents per foot per duct; for his conduit, three cents per foot per duct. This does not include excavation, which is about the same for all. It does not include the cost of handling his removable core.

Your committee have examined samples of these removable cores, and portions of conduits made in this way, and are of the opinion that the invention is simple, ingenious, effective and inexpensive. Furthermore, an invention of an efficient removable core enables monolithic conduits to be made of hydraulic cement, whose properties are already well known. Unlike creosoted wood, it contains no substances which are likely to attack chemically the insulation or the lead armor of cables, and unlike iron it does not corrode. The results, therefore, which can be accomplished by means of this removable core, are unquestionably of value.

Your committee recommend the award of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to Alexander Crawford Chenoweth, for his improved method of laying continuous electrical conduits.

[Signed] CARL HERING,
Chairman Sub-Committee.

RICHARD W. GILPIN,
CHARLES H. RICHARDSON,
G. BETTON MASSEY.

Adopted, June 5, 1889.

[Signed] S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

THE SUBSTITUTION OF GELATINE IN PLACE OF COLLODION FOR PHOTOGRAPHY.

[*Report of the Committee on Science and the Arts.*]

[No. 1451.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 18, 1889.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

THE SUBSTITUTION OF GELATINE IN PLACE OF COLLODION FOR PHOTOGRAPHY, AS INVENTED BY DR. RICHARD LEACH MADDOX, AND FREELY MADE KNOWN BY HIM IN THE PAGES OF THE *British Journal of Photography*, SEPTEMBER 8, 1871,

Report that: They have carefully considered the subject and examined into the merits of the invention claimed by Dr. Maddox. They find that although gelatine had been employed photographically in a variety of ways, and although silver haloid salts had been emulsified successfully with collodion in photographic practice, prior to the publication by Dr. Maddox of his gelatino-bromide process, nevertheless the successful emulsification by him of silver haloids with gelatine and the perfecting of a working process, founded upon it, involved so much painstaking experimentation and investigation and was such a departure from old methods that it merits recognition on account of its marked influence on the progress of photography, on the enlargement of its practice, and the multiplication of its applications in technical and purely scientific directions.

The process, though affording negatives of good quality, was soon improved in regard to the quality and sensitiveness of the plates by different individuals, by the removal of the soluble salts, by heating to higher temperatures, by prolonged digestion, by the adoption of ammonia and by changes in minor details.

In consideration therefore of the novelty of the process and of its value, and of the publication of it without any reservation of rights, your committee recommend the award of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to Dr. Richard Leach Maddox, for the substitution of gelatine for collodion in photography as accomplished by him.

[Signed] CHARLES F. HIMES,
Chairman Sub-Committee.

JOHN C. BROWNE,
JOHN CARBUTT,
SAMUEL SARTAIN,
JNO. G. BULLOCK,
F. E. IVES.

Adopted, May 1, 1889.

[Signed] S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

[Extract from the *British Journal of Photography*, September 8, 1871.]

"Originally thirty grains of gelatine were swelled in cold water, then dissolved by heat, four drams of pure water and two drops of aqua regia being added. To this solution eight grains of cadmium bromide and fifteen grains of silver nitrate were added, forming a fine milky emulsion of silver bromide. Without further treatment this was spread upon glass plates and dried. The plates were tested by exposing them beneath negatives and gave a faint but clear image when developed with a plain solution of pyrogallic acid; intensification with pyro and nitrate of silver followed. * * * So far as can be judged, the process seems worth more carefully conducted experiments, and if found advantageous, adds another handle to the photographer's wheel."

NOTES AND COMMENTS.

CHEMISTRY.

CANAIGRE. BY HENRY TRIMBLE.—The following account of a tanning material, which has several times in the past few years been mentioned as new, or as a possibility for the tanner, is undertaken with a view of relating what has been done toward developing this source, and at the same time calling attention to the fact that, if we encourage home production, we have in canaigre a material which gives promise of superseding the uncertain and much adulterated gambier.

Canaigre is found in large quantity in the sandy soil on both sides of the Rio Grande and northward over a large portion of Western Texas and New Mexico.

Its history is briefly as follows: It is said to have been used in tanning by the Mexicans for over two centuries. Our first information, however, dates from July 9, 1868, when a package of these roots was forwarded for Mr. John James, of San Antonio, Tex., to the Agricultural Department at Washington, together with a letter stating that Mr. F. Kalteyer, chemist, in San Antonio, had found them to contain thirty-two per cent. of tannin.

This sample was mislaid or overlooked until 1878, when it was reported on by the chemist.* This same sample was then found to yield 23·45 per cent. of tannin. A fresh sample was also procured and the tannin estimated in the still fresh root with almost identical result, after making due allowance for difference in moisture. The other constituents reported at that time need not claim our attention at present, further than to notice a considerable quantity of starch, 18·00 per cent.

Previous to this publication by the Government, Mr. Rudolph Voelcker, of Galveston, Tex., published † an analysis of roots gathered in July, 1874. He found 23·16 per cent. tannin, and proved the presence of chrysophanic acid and aporetin. He was not aware of the botanical origin of the plant, but supposed it to belong to the natural order Polygonaceæ. In 1879, Mr. Wm. Saunders ‡ in his report on canaigre stated it was the *Rumex hymenosepalum* of Torrey, and furnished a lithographic plate of the plant in bloom.

At the New Orleans Exposition, 1885–86, in one corner of the section devoted to products from New Mexico, were some of these roots, above which was the inscription, "A new tanning material."

It will be shown later that this exhibit, insignificant as it appeared, attracted the attention of at least one person.

In 1886 § a sample of roots sent to me from San Antonio, Tex., under the name of "Indian Root," was analyzed and the results published under the

---

* Report of the Commissioner of Agriculture, 1878, p. 119.

† An analysis of Raiz del Indio. *American Journal of Pharmacy*, 1876, p 49.

‡ Report of the Commissioner of Agriculture, 1879, p. 364.

§ An analysis of *Aristilochia fœtida. American Journal of Pharmacy*, 1886, p. 113.

common name of "Yerba del Indio," from the impression it was the *Aristitochia fœtida* of the Mexican Pharmacopœia. This impression, however, was corrected by Prof. J. M. Maisch in the same issue, page 115. He suggested, and it has since been found to be correct, that this "Raiz del Indio" was the canaigre root.

That analysis fixed the amount of tannin at 11·66 per cent., but it was found that the root, which was not analyzed as soon as received, had commenced to decay and later it was completely riddled by insects. In this respect my experience differed from that of the Government chemist, who found no change after ten years.

Soon after the New Orleans Exposition, samples of two or three hundred pounds were sent to Chicago for experiments in a number of tanneries there. Mr. E. C. Denig, of that city, has devoted much time since then to studying this material, from its source in Texas to its application in the tanning of hides.

Canaigre consists of heavy globular and fusiform pieces, from two to six inches long and one to three inches in diameter. Externally it is of a dark reddish-brown color, becoming, by age, almost black; internally it is from a bright to a brownish-yellow, according to age and amount of exposure to the atmosphere. When collected, the roots consist of clusters, resembling sweet potatoes. They are found near the surface or sometimes on top the ground, are rapidly dried and at a certain stage cut into small pieces. If allowed to get very dry, they become so hard as to resist any ordinary method of cutting.

From samples of the whole and chipped root, kindly furnished me by Mr. Denig, I have found 17·33 per cent. of tannin. This figure is rather lower than that obtained by other investigators, but the deficiency may be explained by my sample containing more moisture. Dr. H. E. Shucke* has found a total of 28·57 per cent. tannin.

The ground root is at present used in a number of tanneries, and has been found more closely to resemble gambier in its action than any other tanning material. An extract has also been prepared and used, which contains from forty to sixty per cent. tannin, and, it is thought, that in this form it will probably replace gambier.

Should the hopes and efforts of those who are engaged in the development of this material be realized, we will have a source of tannin which is said to be inexhaustible, and which will be the means either of bringing a better gambier into the market, or of driving it entirely out of use here. It is said that the dried and ground root can be delivered in any part of the United States at a price not exceeding three cents per pound. Thus, after a delay of twenty years, this root has reached that stage of practical application when a useful future may be predicted for it, and the persistent efforts of the past four years have every prospect of being rewarded. The presence of so much starch in a tanning material is, perhaps, without precedent, and there are good reasons why this is no disadvantage.

The properties of the pure tannin have not been investigated, and it is

* *Shoe and Leather Reporter*, Oct. 27, 1887, p. 862.

not known whether canaigre red or gallic acid is the product of its decomposition. Crystals have been obtained by agitating an aqueous extract of the root with ether, which do not resemble either gallic acid or catechin. This crystalline compound and the pure tannin are under investigation by me at the present time.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Albany Medical College. Catalogue Fifty-eight Session. 1888–9.
From Willis G. Tucker, M.D.

Alteneder, Theodore. Points about Drawing Instruments. From the Author.

American Analyst. Vols. 3, 4 and 5 (odd numbers).
From A. Hosbach.

American Institute of Mining Engineers:
- Keep. The Influence of Silicon in Cast Iron.
- Fleming. The Influence of Silicon in Cast Iron.
- Orton. The Influence of Silicon in Cast Iron.
- Woodbridge. A Rapid Method for the Determination of Phosphorus in Certain Ores.
- Birkinbine. The Concentration of Iron Ore.
- Edison. The Concentration of Iron Ore.
- Harden. Note on the Koepe System of Winding from Shafts.
- Smock. A Review of the Iron Mining Industry of New York for the Past Decade.
- Walsh, Jr. Supplementary Note on Blast-Furnace Lines.
- Valentine. The Desulphurization of Pyritiferous Iron Ores.
- Billings. Coal *versus* Oil in the Puddling Furnace and in Raising Steam.
- Ives. An Occurrence of Copper Glance North of Lake Huron, with Notes on the Structure of the Locality.
- Jones. A Rapid Method for the Reduction of Ferric Sulphate in Volumetric Analysis. From the Institute.

Anderson, Wallace. Aluminium and its Manufacture. From H. Y. Castner.

Annales des Ponts et Chausèes Personnel. 1889.
From the Director of Public Works.

Association pour Prevenir les Accidents de Fabrique. Collection of Appliances and Apparatus for the Prevention of Accidents in Factories.
From F. Engel-Gros, President.

Atlanta, Ga. Tenth Annual Report of the Board of Health for 1888.
From the Board.

Baltimore, Md. Sixtieth Annual Report of the Board of Commissioners of Public Schools. From the Board.

Button Fire Engine Company. Descriptive Catalogues.
From the Company.

Central High School, Philadelphia. Semi-Centennial.
From John F. Lewis.

Chicago Public Library. Seventeenth Annual Report of the Board of Directors. From the Board.

Chickamauga Land and Iron Company. Announcement.
From Lorin Blodget.

Chronicle Fire Tables. 1889. From the Chronicle Company.

Clark University. First Official Announcement. From the University.

College of Physicians of Philadelphia. Transactions. Third Series. Vol. 10.
From the College.

Colonial Museum and Geological Survey of New Zealand:
Twenty-third Annual Report of the Colonial Museum.
Reports of Geological Explorations during 1887 and 1888.
From the Director of the Museum and Survey.

Conemaugh Valley, from Nineveh to the Lake. Bird's-eye View.
From Chas. Bullock.

Connecticut Agricultural Experiment Station. Bulletins Nos. 98 and 99.
From the Station.

Connecticut Board of Agriculture. Twenty-second Report of the Secretary.
From the Secretary.

Contractors' Plant Manufacturing Company. Catalogue No. 3.
From the Company.

Copeland & Bacon. Hoisting Engines and Mining Machinery.
From Francis Leclere.

Duryee, Schuyler. Assignments of Patent Rights.
From S. Lloyd Wiegand.

Engineers' Society of Western Pennsylvania. Monthly Proceedings for May, 1889. From the Society.

Engineers' Society of Western Pennsylvania. Proceedings of Meeting June 18, 1889. From the Society.

Fairbanks & Co. Catalogue of Steam Specialties, Standard Scales, etc.
From the Company.

Fuller & Warren Company. The Ultimate of Sanitation.
From the Company.

Geological Survey of Pennsylvania. Catalogue of the Geological Museum. Part 3. From the Survey.

Germanischer Lloyd. Internationales Register. 1889. 4ter Nachtrag.
From L. Westergaard & Co.

Gould Rolling Machine Company. Rolled Forgings. From the Company.

Harvard College Observatory:
Annals. Vol. 18. No. 9.
Bruce Photographic Telescope.
A Large Photographic Telescope.
From E. C. Pickering, Director of Observatory.

Hector, James. *Phormium tenax* as a Fibrous Plant. From the Author.

Heisler Electric Light Company. The Standing and Record of the Heisler System. From the Company.

Institution of Civil Engineers. Minutes of Proceedings. Vol. 96. From the Institution.

Institution of Electrical Engineers. Index to Vol. 13. From the Secretary.

Kaiserl. Königl. Geographischen Gesellschaft in Wien. Mittheilungen 1888. From the Society.

Kansas Crop and Weather Bulletin for the Month of June, 1889. From the State Board of Agriculture.

Massachusetts State Agricultural Experiment Station. Bulletin No. 34. From the Station.

Massachusetts State Agricultural Experiment Station. Analysis of Commercial Fertilizers. July, 1889. From the Director of Station.

McElroy Car Heating Company. Will Steam-heated Hot Water Heat Railway Cars? From the Company.

Mercantile Library Association, New York. Sixty-Eighth Annual Report. From the Association.

Mercantile Library of Philadelphia. Bulletin No. 28. From the Library.

Meteorological Council, London:

Hourly Readings. Part. 2. 1886.

Quarterly Weather Report. Part 4. 1879.

From the Meteorological Office.

Meteorological Department Government of India. Indian Meteorological Memoirs. Vol. 4. Part 6.

Meteorological Observations made at the Magnetic and Meteorological Observatory, at Simla. Vol. 2. 1841–1845.

Report on the Meteorology of India. 1887.

From the Department.

Mexico. Observatorio Meteorologico Magnetici Central.

Inundation de la Ciudad de Lagos.

Inundation de la Ciudad de Leon.

Trayectoria del Ciclon de Septiembre de 1888. Three charts.

From the Observatory.

Mills, Chas. K. Cerebral Localization. Lesions of the Sacral and Lumbar Plexuses. Spinal Localization. From the Author.

Milwaukee Board of Public Works. Annual Report for 1888. From G. H. Benzenberg, City Engineer.

Milwaukee. Report of the Commission of Engineers on the Collection and Final Disposal of the Sewage, and on the Water Supply of the City. From the City Engineer.

Minneapolis, Minn., City Water Works Department. Annual Report. From the City Council.

National Electric Light Association. Proceedings at its Ninth Convention. From Allan V. Garratt, Secretary.

National Electric Light Association. Bulletin No. 1. 1889.
Proceedings at its First to Eighth Conventions.
From Allan V. Garratt, Secretary.

Newberry Library. Proceedings of the Trustees for 1888.
From the Trustees.

Newton, Mass. Auditor's Annual Report for 1888. From the City Clerk.

New York Institute for Artist Artisans. First Annual Report.
From the Institute.

New Zealand Institute. Transactions and Proceedings, 1888. Vol. 21.
From the Director.

Ohio Agricultural Experiment Station. Sixth Annual Report for 1887.
From the Station.

Ohio Agricultural Experiment Station, Bulletin, Vol. 2, No. 2.
From the Station.

Peabody Institute. Baltimore. Twenty-second Annual Report.
From the Institute.

Pennsylvania. Annual Report of the Secretary of Internal Affairs, 1888. Parts 1 and 2. From the Secretary.

Pennsylvania Hospital. Report of the Board of Managers. 1889.
From the Board.

Pennsylvania Second Geological Survey. Catalogue of the Geological Museum. Northern Anthracite Field Atlas. Parts 3 and 4. Atlas to Reports H. H., and H. H. H.
From the Secretary of the Board of Commissioners Geological Survey of Pennsylvania.

Pennsylvania State Board of Health. Health Bulletins issued at Johnstown, Pa. From the Board.

Philadelphia. Thirty-fifth Annual Report of the City Controller.
From Robert P. Dechert, City Controller.

Popular Science News. Vol. 22. (Six numbers.) From A. Hosbach.

Price Cook Book. From Price Baking Powder Company.

Regia Accademia delle Scienze dell' Istituto di Bologna. Memorie. Serie 4. Tomo 8.
Note sur les derniers progrès de la question de l'unification du calendrier. From the Academy.

Regia Accademia delle Scienze di Torino. Atti. Vol. 23.
From the Academy.

Rensselaer Society of Engineers. Selected Papers. Vol. 2, No. 2., 1889.
From the Society.

Rochester Machine Tool Works. Catalogue of the Acme Automatic Safety Engine. From the Works.

Roscoe, Sir Henry. Aluminium. From H. Y. Castner.

Royal Cornwall Polytechnic Society. Fifty-Sixth Annual Report.
From the Society.

Scientific American. March 2, 1889. From A. Hosbach.
March 9 to June 1, 1889. From Spencer Fullerton.

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR JULY, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, July 31, 1889.

TEMPERATURE.

The mean temperature for July, 1889, was 71°·2, which is about one degree below the normal, and two degrees above the corresponding month of last year. The greatest departures were in the eastern border counties. The mean of the maximum temperatures was 81°·3; and the mean of the minimum 61°·8. The highest temperatures reported were Charlesville, 96°; Hollidaysburg, 95°; Greenville, 95°; Phillipsburg, 94°; Coatesville, 94°; Grampian Hills, 94°; Bethlehem, 94°; New Bloomfield, 94°, and Philadelphia, 94°. These occurred on the 9th and 10th. The lowest temperatures were Coudersport, 39°; New Bloomfield, 40°; Wellsboro, 42°; Columbus, 42°, and Dyberry, 42°.

July is the warmest month of the year, being two degrees warmer than August, and four or five degrees warmer than June. The mean of the three summer months is two degrees less than July.

ISOTHERMAL LINES FOR JULY.

Lines representing places having the same normal temperature are very difficult to trace over the mountain ranges and deep valleys of Pennsylvania. Observations are usually taken at towns in the river valleys, and such deep depressions have a temperature two degrees higher than that of the country back of them. In preparing the accompanying chart an a'lowance of about one degree was made for such excess. This will explain the lines passing through the northern counties, particularly at places where somewhat higher summer mean temperatures are recorded. In the broader valley of the Susquehanna, the lines may properly be carried sharply along the valley itself.

ATMOSPHERIC PRESSURE.

The barometer averaged slightly above the normal. The highest pressure occurred on the 6th and 7th, and the lowest on the 19th, 20th, and 23d.

PRECIPITATION.

The rainfall for July averaged 6·80 inches for the state, which is an excess of from two to three inches.

The month was very humid and tropical in character. Rains were frequent and varied from light to torrential over areas little distant from each other. In many places heavy downpours occurred, which were disastrous, and entirely local in character. On the 30th and 31st very heavy rains occurred over the eastern part of the state, which caused heavy floods. The Schuylkill was reported the highest since the flood of 1869. Its banks were overflowed, and it is estimated that at one time ten feet of water were over Fairmount dam. The largest totals in inches for the month were: Landsdale, 15·02; Ottsville, 13·19; Coatesville, 12·93; Frederick, 12·69; Pottstown, 12·50; West Chester, 12·49; Smith's Corner, 12·30; Point Pleasant, 12·30. The smallest were Greenville, 1·04; Erie, 1·68, and Columbus, 2·00. The excess of rainfall extended into New Jersey, Eastern New York, and Connecticut; also, Delaware and Maryland.

WIND AND WEATHER.

The prevailing wind was from the west; no severe gales occurred. In some sections large portions of the hay crop were badly damaged during the harvest season by unfavorable weather. Some wheat was injured, and harvesting was generally delayed by frequent rains. The season has been favorable for the growth of all vegetation.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Charlesville, 3d, 10th, 13th, 19th; Reading, 9th, 10th, 13th, 30th; Hollidaysburg, 2d, 13th, 19th, 29th; Forks of Neshaminy, 11th; Quakertown, 1st, 2d, 10th, 13th, 15th, 29th, 30th, 31st; Emporium, 3d, 9th,

13th, 14th, 30th; State College, 1st, 2d, 3d, 13th, 14th, 30th; West Chester, 4th, 9th, 10th, 11th, 13th, 15th, 29th, 30th; Coatesville, 1st, 4th, 10th, 11th, 13th, 15th, 29th, 30th, 31st; Rimersburg, 1st, 3d, 10th, 12th, 13th, 19th, 23d; Swarthmore, 11th, 13th, 15th; Uniontown, 1st, 2d, 3d, 11th, 13th, 19th; Huntingdon, 1st, 14th, 27th, 29th, 30th; Drifton, 10th; Pottstown, 1st; New Bloomfield, 1st, 2d, 3d, 11th, 14th, 29th; Philadelphia, 1st, 11th, 15th; Coudersport, 1st, 10th; Girardville, 2d, 3d, 10th, 29th, 30th; Selins Grove, 2d, 3d, 10th, 11th, 19th, 29th, 30th; Somerset, 11th, 29th; Eagles Mere, 10th; Wellsboro, 1st, 10th, 13th, 30th; Dyberry, 13th, 29th, 30th; Honesdale, 2d, 3d, 10th, 13th, 31st; York, 10th, 13th, 29th, 30th.

Coronæ.—Reading, 28th, ; Wellsboro, 26th, 31st; Dyberry, 7th.

Solar Halos.—Charlesville, 17th; Eagles Mere, 13th.

Auroras.—Quakertown, 15th; Eagles Mere, 28th.

WEATHER FORECASTS.

Percentage of local verifications of weather and temperature signals as reported by displaymen for July, 1889:

Weather, 81 per cent.

Temperature, 91 per cent.

TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.

Displayman.	*Station.*
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.
W. S. Ravenscroft,	Hyndman.
R. C. Schmidt & Co.,	Belle Vernon.
Jesse R. Brown,	Lehmasters.
H. W. Mullen,	Centre Valley.

WEATHER SERVICE F

		PRECIPITATION.		N
	Dew Point.	Total Inches.	Number of Days Rainfall.	Clear.
lleg				
edf	61·2	5·48	13	6
erk	64·1	4·19	14	10
air,	68·0	9·30	10	12
air,	60·0	4·60	12	. . .
radi	68·0	6·22	13	15
ick	64·0	5·17	15	7
icks	. . .	10·36	14	14
ame	68·2	11·54	16	11
ntr	61·0	7·03	10	15
ntr	62·4	4·68	13	12
est	. . .	5·21	12	9
est	66·5	12·49	. . .	. . .
aric	. . .	12·93	16	13
aric	. . .	. . .	7	12
carl	. . .	. . .	. . .	. . .
nto	. . .	7·33	15	13
lum	. . .	. . .	. . .	. . .
awf	. . .	6·62	12	. . .
mb	. . .	. . .	. . .	. . .
upl	. . .	. . .	. . .	. . .
law	65·5	8·68	18	7
e,1	67·0	8·74	13	11
ett	62·0	1·68	10	15
ton	. . .	4·81	12	14
nti	63·7	8·.3	14	12
ian	. . .	5·38	19	7
re	. . .	. . .	. . .	. . .
an	. . .	. . .	. . .	. . .
an	. . .	. . .	. . .	. . .
ern	. . .	. . .	. . .	. . .
Ke	. . .	9·55	15	10
ce	. . .	. . .	. . .	. . .
tg	64·9	1·04	7	11
ha	75·0	12·50	14	15
y,	66·0	9·93	12	17
ad	. . .	6·08	14	10
er,	65·3	8·29	17	6
yl	62·5	7·00	7	21
le	. . .	9·46	14	10
rs	68·0	4·29	·9	16
va	62·2	5·06	7	15
a,	61·3	6·30	16	8
er	52·3	3·06	12	11
ne	61·0	2·00	8	11
ne	. . .	6·53	12	13
,1	. . .	5·55	. . .	. . .
	66·3	4·34	8	13

Ob

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for July, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer.			Temperature.	Maximum.		Minimum				Daily Range.					Relative Humidity.	Dew Point.	Precipitation.		Number of Days.			Wind. Prevailing Direction.			Observers.
			Mean.	Highest.	Lowest	Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum	Mean of Minimum.	Mean.	Greatest.	Date.	Least.	Date.			Total Inches.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
Allegheny,[1]	Pittsburgh,	847	29.996	30.245	29.678	74.0	93.3	10	55.5	16	83.8	65.2	18.6	27.5	17	10.7	23	67.2	61.2	5.48	13	6	10	15	N	N	N	Oscar D. Stewart, Sgt. Sig. Corps.
Bedford,	Charlesville,	1,300	...	...	...	70.4	96.0	12	48.0	16	81.3	62.1	19.2	32.0	17	5.0	26	81.6	64.1	4.19	14	10	13	8	W	W	SE	Rev. A. Thos. G. Apple.
Berks,[1]	Reading,	304	29.997	30.236	29.723	71.8	92.0	9	50.0	16	82.8	63.5	19.3	31.0	6	3.0	4	88.7	68.0	9.30	10	12	10	9	NW	NW	NW	C. M. Dechant, C.E.
Blair,[2]	Altoona,	1,181	...	...	...	74.5	93.0	10, 11	55.0	16, 25	84.4	64.7	19.7	31.0	15	11.0	2	[illegible]	[illegible]	4.60	12	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947	...	...	...	71.6	95.0	10	47.0	16	84.5	59.4	25.1	38.0	17	13.0	31	86.0	68.0	6.22	13	15	10	6	W	W	S	Prof. J. A. Stewart.
Bradford,	Wysox,	718	29.979	30.277	29.696	69.2	91.2	10	44.5	25	80.7	58.0	21.8	34.1	7	8.0	2	83.2	64.0	5.17	15	7	12	12	SE	SE	SE	Charles Beecher.
Bucks,	Forks of Neshaminy,	...	...	...	...	73.2	...	...	...	...	...	...	...	...	...	...	...	...	...	10.36	14	14	7	10	W	W	W	J. C. Hilsman.
Bucks,	Quakertown,	536	29.990	30.220	29.680	70.2	91.7	9	52.7	6	84.1	61.0	23.1	30.7	[illegible]	7.0	2	90.3	68.2	11.54	10	11	9	11	N	NW	SW	J. L. Heacock.
Cameron,	Emporium,	1,030	...	...	...	70.0	93.0	10	41.0	25	83.2	56.0	26.3	39.0	25	12.0	2	73.6	61.0	7.03	10	15	10	6	W	NW	NW	T. B. Lloyd.
Centre,	State College—Agricultural Experiment Station,	1,191	29.914	30.223	29.405	70.3	89.0	10	57.0	15	80.0	63.3	16.7	30.0	25	9.0	3	75.2	62.4	4.68	13	12	11	7	W	W	W	Prof. Wm. Frear.
Centre,	Phillipsburg,	1,350	...	...	...	68.0	94.0	10	45.0	16	84.7	53.0	31.7	38.0	12	12.0	1, 3	...	...	5.21	12	9	10	12	SW	SW	SW	Geo. H. Dunkle.
Chester,	West Chester,	455	29.982	30.235	29.667	72.6	90.0	9	55.0	16	81.4	65.6	14.8	22.0	16	4.0	2	70.0	60.5	12.40	...	...	...	...	...	...	...	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	74.9	94.0	9	52.0	16	82.9	63.9	19.0	30.0	7	8.0	27	...	...	11.93	16	13	11	12	W	W	W	W. T. Gordon.
Clarion,	Rimersburg,	1,500	...	...	...	75.0	92.0	10	56.0	25	80.0	70.0	10.0	30.0	25	3.0	18	...	...	...	7	12	13	6	W	W	E	Rev. W. W. Deatrick, A.M.
Clarion,	Clarion—State Normal School,	1,530	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	...	...	...	70.8	94.0	9	52.0	26	80.7	64.4	16.3	26.0	13	8.0	3, 25	...	...	7.33	15	13	10	8	W	SW	W	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. John A. Robb.
Columbia,	Catawissa,	491	...	...	...	70.8	91.0	9	52.0	16	...	...	...	...	...	...	...	...	...	6.62	12	...	...	...	...	...	...	Robert M. Graham.
Crawford,	Meadville—Allegheny College,	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. B. Derickson.
Cumberland,	Carlisle,	480	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Pague.
Dauphin,[1]	Harrisburg,	361	29.998	30.270	29.7[illegible]6	73.8	92.0	9	57.0	16	81.8	65.8	16.0	26.0	17	7.0	19	77.8	65.5	8.68	18	7	14	10	E	E	E	Frank Ridgway, Sgt. Sig. Corps.
Delaware,	Swarthmore—Swarthmore College,	190	29.973	30.210	29.721	73.0	91.1	[illegible]	5[illegible].8	10	81.8	65.9	15.9	28.2	8	5.3	19	82.0	67.0	8.74	13	11	10	10	NW	NW	W	Prof. Susan J. Cunningham.
Erie,	Erie,	681	29.980	30.280	29.670	70.0	87.0	9	54.0	15	78.0	63.0	15.0	25.0	22	7.0	20	74.0	62.0	1.68	10	15	9	7	SW	SW	SW	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	29.980	30.162	29.724	74.0	89.0	3, 10, 14	52.0	30	82.1	62.4	19.7	28.0	7	11.0	26	76.2	...	4.81	12	14	14	3	SW	SW	SW	Wm. Hunt.
Fulton,	McConnellsburg,	875	...	...	...	72.0	92.0	9, 10	48.0	10	84.7	60.8	23.9	40.0	16	8.0	2	78.9	63.7	8.23	14	12	16	3	S	S	S	Thomas F. Sloan.
Huntingdon,	Huntingdon—The Normal College,	650	...	...	...	70.3	90.0	8, 9	48.0	16	81.5	60.2	21.3	33.0	8	14.0	30	...	...	5.38	19	7	8	10	W	W	W	Prof. W. J. Swigart.
Indiana,	Indiana—State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Albert E. Maltby.
Lawrence,	New Castle,	932	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Wm. T. Butz.
Lebanon,	Myerstown,	474	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Wm. H. Kline.
Lebanon,	Anville—Lebanon Valley College,	339	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Geo. W. Bowman, A.M., Ph.D.
Luzerne,	Drifton—Drifton Hospital,	1,655	...	...	...	67.1	88.0	9	50.0	16	77.3	60.4	16.9	27.0	11, 25	7.0	27	...	...	9.55	15	10	11	10	...	...	...	H. D. Miller, M.D.
McKean,	Smethport,	1,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell.
Mercer,[1]	Greenville—Thiel College,	1,000	29.917	30.158	29.580	68.8	95.0	9	44.6	25	82.8	56.4	26.4	43.0	8	10.2	15	87.9	64.9	1.04	7	11	10	10	SE	...	W	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	...	...	...	74.4	92.0	9	50.0	10	82.0	67.0	14.4	25.0	16	2.0	2	81.0	75.0	12.50	14	15	6	10	W	W	W	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	...	...	...	74.0	94.0	9	54.0	15	83.0	63.0	20.0	32.0	9	5.0	2	78.0	60.0	9.93	12	17	7	7	W	W	W	Lerch & Rice.
Perry,	New Bloomfield,	400	...	...	...	72.7	94.0	9, 10	40.0	25	81.2	59.1	22.1	46.0	25	9.0	31	...	...	6.08	14	10	10	11	W	W	W	Frank Mortimer.
Philadelphia,[1]	Philadelphia,	117	30.0[illegible]0	30.259	29.669	73.8	94.0	9	60.0	16	83.1	67.5	15.6	24.0	6	5.0	2	76.3	65.3	8.29	17	6	9	16	NW	NW	NW	Luther M. Dey, Sgt. Sig. Corps.
Potter,	Coudersport,	1,670	...	...	...	67.2	89.0	10	29.0	25	8[illegible].6	53.8	26.8	39.0	7	13.0	3[illegible]	79.0	62.5	7.00	7	21	6	4	NW	NW	NW	C. L. Peck.
Schuylkill,	Girardville,	1,000	29.998	30.214	29.573	72.6	90.0	10	53.0	6	81.0	62.9	18.1	29.0	18	8.0	2	...	...	9.46	14	10	4	17	W	W	W	E. C. Wagner.
Snyder,	Selins Grove,	445	...	...	...	74.4	89.0	9	57.0	25	7[illegible].9	68.2	11.7	46.0	28	33.0	25	75.2	68.0	4.29	[illegible]	16	6	[illegible]	SE	SE	SE	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	68.5	89.0	11	45.0	16	74.1	57.9	21.2	35.0	6	9.0	30	83.1	62.2	5.06	7	15	4	12	NW	NW	NW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	30.010	30.230	29.964	67.5	86.0	10	51.0	16	73.8	62.1	11.7	22.0	6	4.0	19	83.2	61.3	6.30	16	8	11	12	NW	NW	NW	E. S. Chase.
Tioga,	Wellsboro,	1,327	29.[illegible]42	30.275	29.642	70.3	90.0	10	42.0	25	8[illegible].3	61.1	19.2	34.0	25	14.0	19	73.6	52.3	3.06	12	11	8	12	N	N	S	H. D. Deming.
Warren,	Columbus,	1,410	30.081	30.372	29.843	68.1	88.0	10	42.0	25	...	...	...	...	...	...	...	78.2	61.0	2.00	8	11	15	5	SW	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	66.6	89.0	10	42.0	25	77.3	52.9	24.4	34.6	18	7.0	31	...	...	6.53	12	13	8	10	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	66.4	8[illegible].0	10	44.0	25	75.8	57.0	18.8	30.0	18	6.0	20	...	...	5.55	...	...	...	...	...	...	...	John Torrey.
York,[1]	York,	385	29.956	30.223	29.702	74.5	95.0	10	52.5	16	83.7	64.8	18.9	29.0	7	6.5	19	72.7	66.3	4.34	8	13	10	8	NW	NW	NW	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

Erie.	New Castle.	Greenville.	Coatesville.	Dyberry.	Coudersport.	Honesdale.	Quakertown.
. .	. .	. .	·47	. .	. .	·48	·[illegible]
·55	. .	·06	1·07	·75	·20	·30	·[illegible]
·23	. .	·47	·16	·37	2·10	·12	·[illegible]
. .	. .	·08	1·02	·45	. .	·48	·[illegible]
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	·03	·56	. .	·2[illegible]	. .	·1
·01	. .	. .	·87	·61	. .	·09	·5
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	·04	1·02	·17	·50	·12	·6
·08	. .	·06	. .	. .	. .	. .	. .
·18	. .	. .	1·05	1·46	·9[illegible]	1·50	2·1
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	·0
. .	. .	. .	. .	. .	. .	. .	. .
·05	. .	·30	·20	·26	. .	·29	·4
·05	. .	. .	·08	·07	. .	. .	·1
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	·05	. .	. .	. .	. .
. .	. .	. .	·44	·56	1·90	·51	·6
·52	. .	. .	·05	. .	. .	·02	·2
·01	. .	. .	·07	·96	. .	·91	·1
. .	. .	. .	3·02	·66	1·20	·65	1·7
. .	. .	. .	2·80	·21	. .	·08	2·2
8	. .	1·04	2·93	6·53	7·00	5·55	11·5

PRECIPITATION FOR JULY, 1889.

Day	Erie.	New Castle.	Greenville.	Columbus.	Pittsburgh.	Uniontown.	Clarion.	Indiana.	Smethport.	Somerset.	Grampian Hills	Emporium.	Blue Knob.	Phillipsburg.	Huntingdon.	Hollidaysburg.
1						.03					1.48	.30	.30	.95	.31	.49
2	.55		.06		.04	.02					.05	.19	.20	.20	.02	2.83
3	.23		.47	.68	.18						.98	.11	.40	.45	.32	.29
4			.08	.15	.29	.80				1.00	.16	1.30		.13	.25	.19
5															.06	
6															.07	
7															.01	
8																
9												.42				
10			.03	.16												
11	.01				.20	.27				2.30	.05		.20	.15	.06	.17
12				.04											.01	
13			.04	.20	.08	.54					.56		.70	.45	.16	.44
14	.05		.06	.68	.31								.20		.59	.01
15	.11				1.30	.83				.02	1.84	.75		2.03	1.20	.33
16																
17																
18				.05												
19	.05		.30		.52	1.23					.04		1.40		.18	.42
20	.03												.10	.13	.09	
21																
22																
23						.15					.10					
24											.06			.02		
25																
26															.05	
27					1.41	.02				.45	.80	1.87	.30	.25	.70	.27
28	.32															
29	.01			.04	.12	.21				1.03	.06	.04	.50	.05	1.00	.35
30					1.03	.26				.20		1.97	.30	.40	.22	.21
31						.45				.06	1.15	.08	.10		.13	.22
	.68	..	1.04	2.00	5.48	4.81	..	..	..	5.06	7.33	7.03	4.70	5.21	5.38	6.22

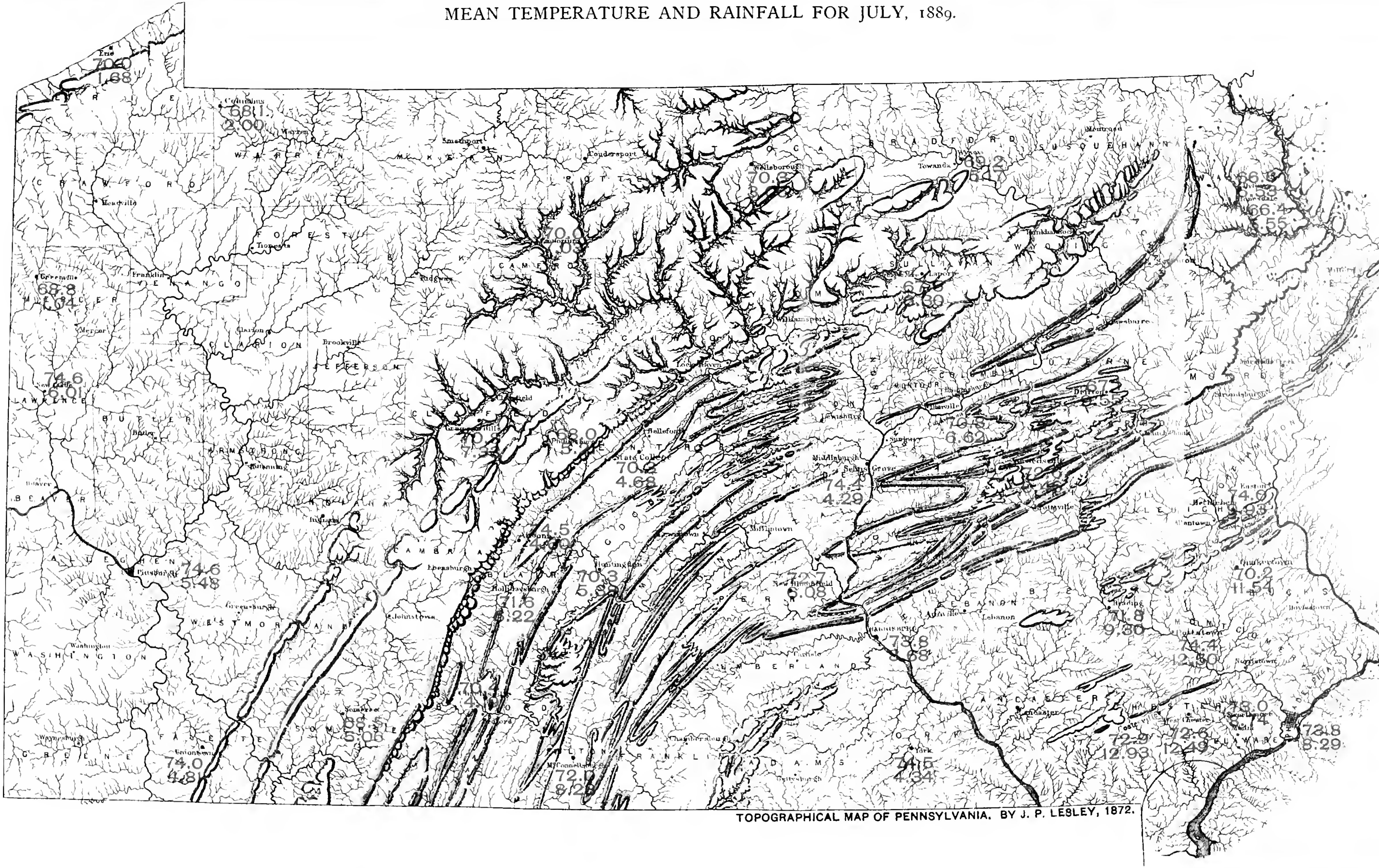
Day	Altoona.	Charlesville.	McConnellsburg.	State College.	York.	New Bloomfield.	Carlisle.	Wellsboro.	Nisbet.	Harrisburg.	Selins Grove.	Eagles Mere.	Wysox.
1	.12	.53	.80	.53	.66	1.30		.19	.60	.54	.27	.65	1.17
2	.23	.06	.71	.03	1.01	.68		.10	.30	.62	.31	.69	.01
3	1.20	.36	1.04	.35	.02	.30		.08		.14	.72	.32	.20
4	.15	.33	.25	.10	.03	.54		.46		.58	.10	.22	.03
5													
6													
7													
8													
9													
10		.30						.20			.15	.50	.26
11	.13		.17	.08		.40		.10	.10	.50	.04	.74	.07
12										1.40			
13	.37	.10	.07	.43		.40		.08	2.30	.04	.03		.09
14		.07		.08		.78		.06	.50	.02			1.39
15	1.45	.51	.30	1.04	.76			.28		1.30	1.24	.85	.04
16													
17													
18													
19		1.08	.75	.06	.05	.04				.10		.24	.03
20	.14	.01				.01				.08		.30	.04
21													
22		.02	.14							.18			
23										.02			
24													
25													
26		.16	.13	.63		.15				.04			.36
27	.29		1.71			.35		.74	.50	.12	.39	.18	.20
28				.19						.08			
29	.10	.30	1.04	.35		.55		.12	.30	1.86	.78	.62	.70
30	.28	.36	.92	.81	.68	.28		.65	.30	.68	.19	.76	
31	.14		.20		1.13	.30			.20	.38	.09	.23	.58
	4.60	4.19	8.23	4.68	4.34	6.08	..	3.06	5.10	8.68	4.29	6.30	5.17

Day	Catawissa.	Girardville.	Drifton.	Reading.	Pottstown.	West Chester.	Coatesville.	Dyberry.	Coudersport.	Honesdale.	Quakertown.	Swarthmore.	Philadelphia.
1	1.16	2.00	1.35		2.20	.46	.47			.48	.90	.21	.13
2	.04	1.31	.50	.76	.70	1.68	1.07	.75	.20	.30	.54	.52	.51
3	.57	.29	.38	.02	.07	.25	.16	.37	2.10	.12	.45	.06	.21
4	.07	.33	.25	.77	.32	.65	1.02	.45		.48	.54	.63	.61
5													
6													
7													
8													
9				.03	.10	.17							
10			2.10	.90	1.10	.23	.56		.2[illegible]		.11		.04
11	.24	.35	.70	.70	.80	.48	.87	.61		.09	.56	.30	.71
12													
13	.06	.11		.20	1.32	2.05	1.02	.17	.50	.12	.63	.30	.23
14		.33											
15	1.13	1.09	1.10	1.80	2.40	1.08	1.05	1.46	.90	1.50	2.14	1.58	.48
16													
17			.15	.06							.05		.01
18			.24										
19		.25	.06	.03	.08	1.14	.20	.26		.29	.48		.33
20				.17		.91	.08	.07			.19	1.00	.43
21													
22													
23													
24						.03							
25													
26	.07	.13				.03	.05						.26
27	.50	.34	.39	.50	.40	.44	.44	.56	1.90	.51	.64	.57	.88
28			.31	.02		.07	.05			.02	.21	.53	.15
29	1.13	1.37	.42	.38	.10		.07	.96		.91	.18	.05	.16
30	.87	1.05	.81	1.36	1.05	1.17	3.02	.66	1.20	.65	1.72	.31	1.15
31	.78	.51	.79	1.60	1.86	1.65	2.80	.21		.08	2.20	2.68	2.00
	6.62	9.46	9.55	9.30	12.50	12.49	12.93	6.53	7.00	5.55	11.54	8.74	8.20

Day	Soisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Neshaminy	Germantown.	Point Pleasant.	Bethlehem.
1			.57				.01			.72
2			.87							.93
3	2.22	2.20	.03		1.15		1.40	1.93		.04
4	.80	.40	.70	2.29	.63	2.63	.44	.71	1.30	.30
5										
6										
7										
8										
9			.01							
10	.57		.58		.42					1.6[illegible]
11	.73	1.44	.15	.74		1.15	.23	1.14	.7[illegible]	.04
12										
13	.47	.53	.24	.30	.04	1.00	.29	.28	.24	.2[illegible]
14			1.52							
15	1.62	2.48	.04	.45	1.99	1.94	2.26	1.00	1.40	1.04
16										
17						.43		.18		
18										
19			2.79	.06	.18	3.50			.01	.55
20	1.39	.34		4.36			.84	1.21	3.95	
21										
22										
23										
24										
25										
26			.73		.74					
27	.70	.27	.03	.78			.75	.61		.63
28	.20	.22	.08		.40	.45	.05		.88	
29			.24			.57			.01	.54
30		.21	2.60	.15	1.55				2.49	
31	3.06	4.60	2.01	3.17	1.77	3.35	4.09	3.44	.72	2.72
	11.76	12.69	13.19	12.30	11.87	15.02	10.36	10.50	12.30	9.93

T. F. T.

MEAN TEMPERATURE AND RAINFALL FOR JULY, 1889.

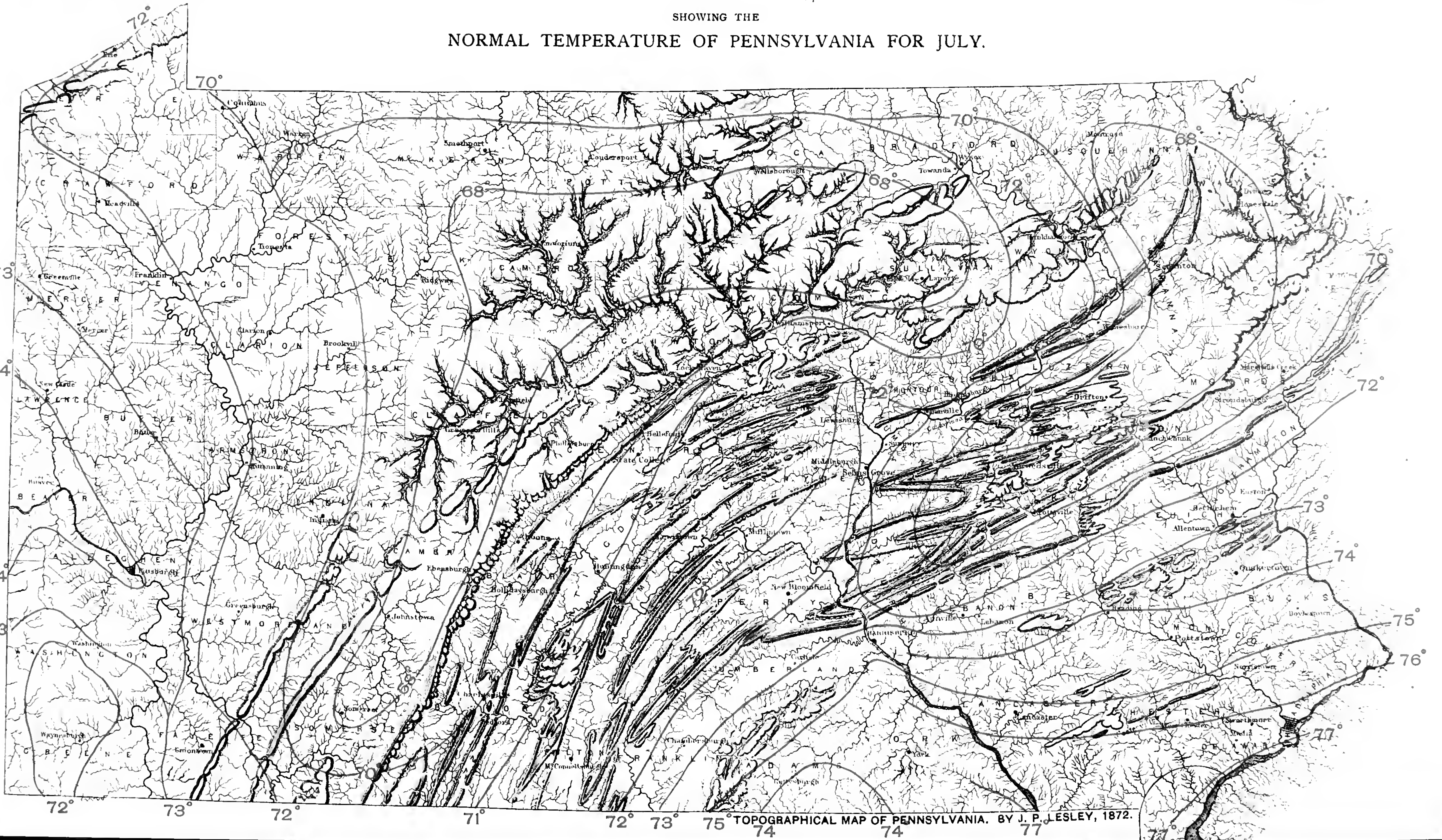


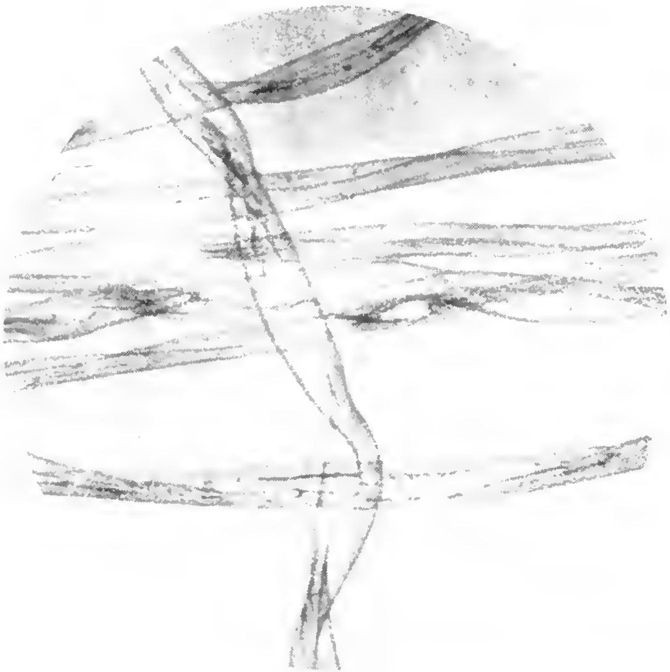
TOPOGRAPHICAL MAP OF PENNSYLVANIA. BY J. P. LESLEY, 1872.

ISOTHERMAL LINES,

SHOWING THE

NORMAL TEMPERATURE OF PENNSYLVANIA FOR JULY.





A.—Upland Cotton—Coarse and not very well developed.

B.—Upland Cotton—Raised from third-year carefully selected seed.

C.—Ozier Cotton from the Mississippi Delta—Fine, very strong and well developed.

D.—Ozier's "Silk" Cotton from the Mississippi Delta.

PHOTO-MICROGRAPHS OF COTTON FIBRES (DIRECT), SHOWING SPIRALITY, SIZES COMPARATIVELY, STRUCTURE AND OIL CELLS.

[Engraved for the JOURNAL by permission from *The Cotton Fibre and Cotton Spinner*. Copyright by Thos. Pray, Jr.]

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVIII. OCTOBER, 1889. NO. 4.

THE COTTON FIBRE.*

BY THOMAS PRAY, JR.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *Friday, December 2, 1887.*]

The Speaker was introduced by Dr. WM. H. WAHL, Secretary of the INSTITUTE, and spoke substantially as follows:

MR. CHAIRMAN, MEMBERS OF THE FRANKLIN INSTITUTE, LADIES AND GENTLEMEN:

The cotton fibre is one of the subjects with which we are most intimately acquainted, and fifty of the sixty million people of the United States are in closer contact with the

* This lecture was copiously illustrated with the aid of the projecting lantern. A few of the pictures shown have been here reproduced (see *Frontispiece*), because of their value as exhibiting the contrast in physical characteristics. These illustrations are copyrighted and used by permission from *The Cotton Fibre and Cotton Spinner.*—(COM. PUB.)

cotton fibre than with anything else, and three-quarters of the other ten millions buy cotton with their wool, as you are probably aware; and yet there are very few indeed who know very much about the fibre, and not one in a thousand of the cotton manufacturers of the country who can tell you very much about the fibre except that they grind out "so many" bales a week, and make so many bales a week of cotton sheetings, shirtings or something else out of a fibre of which they know very little indeed. I believe, in my profession as an engineer, in counting, weighing and measuring everything, and making all my deductions so clear that they are of the "knock-down" order, for, in that way, I can compel attention and make my statements based only upon fact, thus compelling also agreement with my showing, and it is with that purpose in view that I propose to show you to-night, instead of asking you to take my observations without the proof positive being also introduced. All the pictures that I may show you this evening are my own work in the cotton field, as are the photo-micrographs, which you will have thrown on the screen, so that you can see exactly as I have seen, all the physical features of the cotton fibre as far as I can see them, with the exception that from several hundred slides I have been, on account of time, compelled to select a few, some thirty in number, instead of several hundreds. I am also going to tell you at the start that my "hobby," as some spinners are pleased to call it, has been ridden to some purpose, and that some few cotton spinners are making use of the microscope in their cotton mills now, and are really beginning to understand that there is a better way of buying cotton, or mixing it after it is bought, than the old way. Just imagine a man going into a darkened room to buy silks, and depending upon "feeling" with his fingers; he might tell that the fabric was silk, but what could he tell about the color or texture? So, in buying cotton, what could a man tell about a cotton fibre which is all the way from $\frac{1}{900}$ of an inch in diameter for the coarsest Upland, to $\frac{1}{1260}$ for the best New Orleans, or Gulf, and $\frac{1}{2000}$ for the best Sea Island cotton, which is raised in the United States? And yet from 1,500,000 bales

upwards are worked in the United States in this blind way of guessing, or supposing, and turning out such goods as it happened to produce.

The subject is interesting from more points than one and I will now proceed (with the assistance of my friend at the lantern) to show you exactly what I am going to talk about. The first is the locomotive upon which I arrived at the scene of my operations in the cotton field. You will see that the trade-mark of the Baldwin Locomotive Works, Philadelphia, is upon the front of the engine. There is nothing peculiar except it is a wood-burner, and the scenery is peculiarly Southern. The next is a scene clearly Southern, and represents such a crowd as I found one Sunday afternoon in an out-of-the-way country town, where the people were very much surprised at our appearance. In the next, you will have a view of the planter's house, which was my home during all my tramps for four years during the cotton planting and picking seasons; you will see in the strong sunlight just what I saw when looking through the lens of my camera; the house you will see is set up three and a half or four feet from the ground, on account of moisture, and for sanitary reasons; these houses are usually only one-story high, with a broad stoop, and are very pleasant, I can assure you. In our next, we have one of the most beautiful scenes in nature; although our magazines and other literature have a great deal to say about the grandest sight in nature, but, after travelling pretty thoroughly in various countries of the world, I have never seen anything to my own eye more beautiful than a cotton field, just as you see it now on the screen. This is an Upland field, and the cotton is fully open, not quite ready for the picking. Here we have not the "ship of the desert," which, if any of you have ever travelled in the Holy Land, you will remember, but you have the ship of the "cotton field and his navigator," the negro and the mule; while in the distance you will see the "quarters" where the negroes live, and of which you will soon have a very much nearer and plainer view. In this one you have a first-rate view of the bottom land cotton field, perfectly white with bloom, in which you will see the

planter and two boys, and when I tell you that Major Jones is five feet ten inches high, you will be able to judge that the cotton is pretty nearly three feet high, as it comes fully up to his hips. In the next, you have a nearer view of the cotton pickers in working costume. You will notice that each one has grasped a cotton boll in the right hand, while with the left they pick out the fibre from the shell and leave the shell on the stalks of the plant, but put the fibre or "lint" in the "pocket," which you will see each one is furnished with, hanging to the side; this is a woman and her two sons, just as I found them in the field. Here we have the cotton picker again, a nearer view, very much; you can see that very little clothing is worn, and very little outfit is necessary. In this view we have the quarters as they stand in the fields all over the thirteen or fourteen cotton-growing States. The building is, as you will see, of the common hard pine, about 10 x 12 or 12 x 16 feet on the ground, only a single story high, with a mud chimney, sides only battened and the roof covered with rough boards and shingles; in these places the families of negroes live, anywhere from two to a dozen, while very many of the negroes have little houses of their own, which are better somewhat. You will see the mother and her three boys just as I found them after the forenoon's work, each with a pouch or "pocket," while the mule and boy are probably sent from the planter to tell the pickers where to work in the afternoon. In the next, you will see how the pickers get their pay for the work done. Here are the three sons of the planter, with the colored boy and the big cotton baskets. You will see, also, the heads of the horses. The cotton is taken from the pockets or pouches and put into the baskets, and you will see the scales, and the smallest boy has a book in which the weight of each basket is entered, and then the cotton is put into the wagon, and then, in too many cases, the cotton is put into piles on the ground, where it waits for ginning and for the rain; here very much of the cotton is spoiled, and very much, indeed, is materially injured by rain and dampness, etc.; but on the best regulated plantations it is housed until ready for going to the steam gin.

Here we have the cotton in another stage, or, as the negroes usually speak of it, "gwine to town;" you will have no trouble in this picture in telling that the colored people have taken in old uncle and auntie, besides the driver, and the journey to town will be one of the features of their next week's conversation.

This brings me to the "ginnery," where most of the cotton which is carefully raised and kept all right is ultimately spoiled, as far as the spinner goes. The competition in the ginning of cotton has been fierce. Steam gins have been built all over the South, and the cotton is practically ground up, mutilated or anything that you choose to say, except that it is properly ginned. But here you will have one of the few old-time cotton ginneries and presses that are standing. When I say old-time, it is with reference to before-the-war times. The gin-house you can see under the house proper, where the mules are attached to the wooden frame which carries a cast-iron segment upon it, into which a gear-shaft plays, upon the end of which is a pulley which drives the gin, which is put up in the second story, where the cotton is put after picking. The right-hand end of the house is what is called the lint-room, into which the cotton is sent by the action of the gin, and from this lint-room the negroes take the cotton and put it into the press, which is under the double roof, which you see farther at the right. The long, angular timbers which you see, are the levers by which a screw is worked, and you can, perhaps, imagine what the work was on rainy days or when the crop had been early picked. Many and happy have been the days that I have spent in listening to the melodies which were the universal accompaniment of this stage of the cotton crop, but those days have now gone. The march of improvement has displaced them with the steam gin, located in town, where the cotton can be sent off to the mill in an hour, or by the first train after the bale is ready.

Our next is a Southern town; this is one of very many that I have visited and there is very little difference indeed between them. You will see the usual crowd of loafing populace under the broad piazza; you can see the locks of

cotton lying in the street, see the load of cotton bales on the wagon and the three people who are gathered near it, discussing the price probably, one being the planter, another the merchant, who has probably a mortgage on the crop of which the bales are a part, and the other, as you will see from his black face, is the driver. It does not require any great effort to see the words "Bar Room," but whether they are in greater number than they are in Philadelphia, I cannot say. The next is a cotton plant, which, as you will see, broke down under its load in the field, and I was obliged to tie it up so as to photograph it. This was large Upland cotton, and had 227 bolls upon it; if a whole acre could have been raised as good as this, it would have yielded over four bales, of 450 pounds each, for each acre. The next is a boll of cotton, perfect and beautiful. The next is an arrangement of six bolls of different cotton, all arranged upon the same field, so that you can begin the study of the physical difference in cotton. In these six bolls you will find all the difference that you can find in an hour's study of 500 faces, if you will stand on Chestnut or Market Street here at any hour of the day. The upper central is a poorly developed boll of Upland, grown upon poor soil. The lower middle boll was grown upon better Upland soil. The lower right-hand is good Upland, upon well-fertilized soil, and the upper right-hand is Upland cotton grown upon bottom land; while the lower left-hand is Mississippi cotton, the best in the world, excepting only that which is called Sea Island. Now as we proceed you will find the same physical characteristics in a fibre of cotton that you can so plainly see in these six cotton bolls, and the differences in the fibres when you have studied them for a little while will, I am sure, convince you, each and every one, that cotton is capable of being worked differently for different purposes, and with a very great difference in results, if only we can make the selection possible and practical. As you have seen the Upland cotton in the field, before I commence the fibres I will show you the bottom land or low-land cotton as it grows. In this slide, as you will see, the cotton plants are taller, stronger and very much thicker in their growth;

in fact, it is almost impossible when the cotton is fully grown to go through a field of this cotton; and the fibre is like the plant, longer, stronger and more of it on a boll.

We will now begin on the fibres. In this you have a photo-micrograph of a few fibres of cotton taken from some of the best Pernambuco cotton. It will be noticed that it is rather flat and that the fibres are more of the nature of narrow tape. The edges are not thickened and, as you will see in the slides that follow, there is very little or no spirality in the fibres. The oil deposits are few indeed and not very marked. The next slide is from Upland cotton, which is not very well developed (see *Fig. A, frontispiece*). It will be readily seen that the cotton is not strong and robust in appearance, but that the fibres are weak in their outline, not very well thickened on the edges, but that the spirality is more noticeable than in the slide last shown. There are some traces of oil deposits, but it is of the same not clearly-developed type—it will be found by the spinner that the cotton will have the same actual effect in the machinery, and the resultant goods will be weak and uneven, just as the cotton appears on the screen now. No one in this audience will have the least trouble in noticing all the different features between the cotton fibre now on the screen and the one which immediately preceded it. This is Upland Georgia cotton, raised in 1881 or 1882, from seed carefully selected from the first picking and the most perfect bolls; the cotton fibre, as you will notice, is beautifully developed, clear in its outline, well-formed, full of oil deposits and very good spirality (see *Fig. B, frontispiece*). The average crop of this cotton was one and one-quarter bales per acre, where in the old times before the war one-half a bale per acre "was a pretty good yield." This cotton was raised by Major James F. Jones, a native Georgian, living in Troup County. He commenced farming upon the small farm idea, after he found himself getting poorer and poorer after the war, running under the old idea of as many mules as he could work; he commenced using fertilizers and planting a few acres and taking care of them, instead of planting a great many acres and

letting them go in the shiftless, not-taken-care-of way, that was the usual practice. When the Major made his appearance at the Atlanta Exhibition in 1880, and in his modest way made the statement of what he was doing, his statements were doubted, in fact; it was even intimated as probable that "the Major lied." I had read the articles in the *Atlanta Constitution*, and found the Major out upon my arrival there, and afterward had the pleasure of introducing the Major to Mr. Edward Atkinson and his party of New England cotton-spinners upon their arrival there. Mr. Jones has done very much indeed to reform the slack, shiftless ways of farming, and I am glad to say has been successful as far as dollars and cents go. This cotton has been spread all over the South, and the seed sold at $2 a bushel, when the common cotton-seed was a drug at twelve and one-half to sixteen cents a bushel. This particular sample of cotton that I gathered in the Major's cotton field with my own hands remains almost the best developed, strongest and most valuable of any cotton that I have in my collection of thousands of samples, from all sorts of soil and countries, with the exception of Sea Island, and the fine high-grade cottons which you will presently see from the Delta of the Mississippi, where the finest cottons in the world are raised, without any exception whatever. Major Jones' cotton, unlike very many of the "hybrid cottons" and "seedling cottons," which have appeared on the market and soon disappeared, has never changed, but has grown in favor, and when kept pure, has made a material change in the yield in different soils, and is perfectly available as a "cropping" cotton, as the Southern people say.

The finest cotton raised anywhere in the cotton fields of the world, is the Mississippi Delta cotton; beautiful in its structure; perfect in its development; full of oil deposits, with a spirality of nearly 400 per inch, making very strong yarn, capable of coloring all the delicate shades, like pink, light colors, and bleaching in the most perfect manner (see *Fig. C, frontispiece*). If you will compare this cotton in its appearance only, with any other that has been shown, you will have no more trouble in reaching your own conclusion,

than if you were looking at a beautiful oil-painting from the hands of one of the masters or at a six-penny daub. And the physical characteristics are as clearly shown and follow in their working as the appearance of the cotton on the screen with that which has been or which will be shown. This particular cotton has a diameter of about $\frac{1}{1600}$ of an inch and is simply the "perfection of cotton." This slide shows the greatest possible contrast; it is one of the many good-for-nothing hybrids and seedlings and is not now grown to any extent. It requires very little more than to say it is worthless for anything, except wherever weight is required; it is lacking in spirality, oil deposit and development, and is easily disposed of. But who can tell this from the usual examination that is made by pulling a few fibres through the fingers? That is the question which makes or breaks a mill and its owner, and is for you to consider as you follow the subject along.

This is a micro-photograph, as indeed all the slides shown are, but it is a very much higher power than the others, and is shown so you can see the cell walls and deposits clearly. In the case of the "bubble," apparently you see the cell flat, and in the next fibre above it, you will see the same oily deposit; but you are, in the second case, looking at the edge of the cell or multitude of cells. There are many very foolish ideas about cotton, and one is that it has a unicellular structure, or with a single cell. Some three years ago, a little argument was had in Boston, and it has been told that a person with an itching for standing as a microscopist made the assertion that the oil deposits were simply air bubbles, and some idea was put forth of drawing them out with a glass-rod heated with a Bunsen burner. Ignorant people sometimes make themselves ridiculous, but seldom in such a way as this (and it was published as a fact), and, perhaps, some of you Philadelphia spinners can secure the services of the ignorant person to drive the air-bubbles out of the bales of cotton you are working.

In this slide you are again looking at a Mississippi cotton, a special hybrid, raised upon the best soil and highly fertilized, by Colonel Ozier, near Corinth (see *Fig. D*,

frontispiece). This is almost as perfect as best Sea Island cotton, and is very little removed from it, except in its length; this particular cotton, not the finest, is nearly $\frac{1}{1600}$ of an inch in diameter, has from 400 to 440 spirals per inch, very well developed, indeed, full of oil deposit, and if you will look at the edge of the fibre, about in the middle of the field, it has the appearance of the side of a chain, so that you can readily see the edges of the links. This is one of the most beautiful cottons I have ever seen from any country, and Colonel Ozier has made a specialty for some years of raising it. This is the kind of cotton that is worth many millions. It is not a question of selling, but how much can I get? To my mind, there are very few subjects in the vegetable kingdom more beautiful than this particular cotton fibre.

Here we have another specimen in the "seedling" line of cotton. This was introduced, and from its very showing and the full and general appearance, it "took" among the buyers. There are middlemen in the North who bought it largely for two years. They do not buy it now, and it would be regarded as a breach of courtesy to ask them anything about seedling cotton. It is fairly well developed, but very irregular, indeed, lacking in spirality, having but a limited oil deposit, uneven in size, and it works by filling the mill with "flyings," or small particles of very short fibres, covering the machinery completely up, and makes less pounds of goods for each hundred pounds of cotton than almost any other cotton you can buy.

Almost all the photo-micrographs which have been shown you have been "projection," as it more nearly resembles the actual appearance under the lens of the microscope in a practical way. The slide now upon the screen is for definition and is by an immersion lens; in this view you can see the wrinkled appearance of the fibres as plainly as you can see the veins on the back of your hand; if you will take pains to study them for a moment, you will readily observe that they have no particular direction, nor, indeed, any spiral tendency or follow any line, but are really at all sorts of angles to the length of the fibre; as the fibre matures,

the watery portion of the matter contained in the fibre is evaporated by the sun after the shell of the boll breaks open and the oil-wax is hardened in this process and becomes visible; and the more oil or wax in the cotton the stronger the cotton is and the less liable it is to electrical disturbances in the cold, dry weather, or to "varying in numbers," of which we hear so much in the "dog days" or wet weather. If you will study this particular slide, you can see the analogy between the various slides already shown and this one in particular. Dyers and bleachers of fine cotton have their share of trouble in the working of cotton, and find spots which will not take color at all, or unevenly, etc. In this slide you have quite a number of cotton fibres which have been mordanted, or prepared for coloring. There is no trouble whatever in discovering a great difference between the fibres, for their formation is clearly apparent and the peculiar markings which you observe show that in some parts of the fibre the mordant has taken hold and in others there is very little preparation for the coloring process which is to follow. Some of the fibres, you will notice, have taken up the solution in one part of the fibre and others in another; some of them show the edge and others the central portion ready for coloring; and it is not a matter of patience or pains by the dyer, but it is a matter beyond his reach, viz: the physical peculiarities of the cotton fibre which will not take the mordant, and we have often in our dye works or print works some pieces which cannot be either printed or colored anything else than black, and frequently the higher colors have to be "gone over" with the black on account of spots in them, which cannot be remedied by any known process of the art at the present time. It may be proper right here to observe that the microscopic examination of cotton has quite as much to do with the dyeing, printing, bleaching, etc., of cotton as with the work in the spinning-mill, and a vast amount of money is spent every year by the dyers, bleachers, printers, etc., that might be saved if a little common sense were exercised in the buying of cotton for the special purposes for which the goods are destined. Some very curious results have

come under my own observation during the past ten years in this respect, where each party has made absolute claims upon the other in cases for damage; and when observed carefully, it has been found that neither party could have avoided the result with the "cotton which was used," and yet, as a general thing, cotton-spinners, dyers, bleachers, printers, etc., ridicule the microscope as allied to the cotton mill!

In the following out-of-the-question explanations of the structure of the cotton fibre, which no person on the earth to-day knows positively in its completeness, some experiments have been made in dissolving cotton in various chemical solutions. The slide now upon the screen shows one of the most important. In this, you will clearly see that the outline of the fibre is plainly shown, so that there is an exact difference in the condition of the fibre in its present state or as to what it was in its completeness; it is a somewhat curious fact that the fibre dissolves very rapidly at first and more slowly as the inner layers are exposed to the action of the chemicals. The oil cells are the very last to disappear, partially because they are inside, but they are a great deal longer than all the rest of the fibre in dissolving; some thirty to thirty-six hours are required for complete dissolution in the strength of solvent used, and the slide shown was taken at about twelve hours from the mounting. It will be noticed that the fibres which are best developed are still plainest in their outlines, while those which show incompleteness are almost entirely destroyed. That there is a close analogy between the serviceableness of the cotton fibre in its completest development in the field, as to future usefulness, there is in my own mind not a particle of doubt. This is only a single slide, regarding the fibre chemically in this direction, but in connection with the one just shown, it seems to me all that is required in order to base an opinion upon.

We have heard a great deal about poor ginning. Cotton manufacturers complain about poor ginning, and if you will examine with a little care for a moment what is clearly seen on this slide, you can imagine it multipled by millions in

every bale of cotton and not go far wrong. The end fibres are mutilated as though torn by some mechanical means, and you will see several of them in the same field. The fibres, as you will see, are torn for some considerable length, and are shown with the short pieces pretty well in focus. Philadelphia being the city of the mechanic, it may be well to say right here that there is no field of speculative work that promises any more or richer return than the building of a good cotton-gin, one which will take the cotton off from the seed gently but clean; one that can be managed by the least possible mechanical talent, and such a machine will readily return to its inventor a million dollars quicker than in any one business that I know of. It may be well to remark, however, that the parties who take it up must be patient, faithful and capable of fighting. For Whitney died poor and discouraged, because he was robbed of his rights by the great American machinists, who stole his invention but laughed at his efforts to obtain something for the inventing. Since that time two very important inventions have been stolen, respectively one by an American and the other by an English house of machinists. There are cotton-gins put upon the market to-day which are entirely unworthy of the name of gin; they simply tear cotton all to pieces, and the spinner buys and pays for what is found all over the mill and machinery, and which never gets any farther than the sweepings, and goes into the "waste." At the time of the Atlanta Exhibition, in 1880, Mr. Edward Atkinson brought out the fact that I was making this investigation, at the same time that he told the people there that the harvesting of the crop of cotton was growing worse and worse. The first statement I can forgive him, though it has caused me any amount of trouble; the second was the truth, and if he had stated the whole truth he could have put it a great deal stronger. Since the time, when he made the statement, there have been a dozen or more different cotton-gins covered by patents which are somewhat changed to put on the market, which simply make the cotton worse instead of better. The sample shown you is not an extravagant one. It can be found in any bale of cotton any day of the week and in any

mill wherever cotton is worked into yarn, cloth or other goods. The cotton growers, factors, merchants, planters, middlemen and all the rest, if there be any, want a cotton-gin. Whether they will get any more for good than poor cotton is a very discouraging problem. I do not believe to-day that the New England cotton-spinners would pay a cent a bale for clean cotton or for better ginned cotton. If they can buy dirt or trash for a little less money they will buy it, or if they can buy it through some favored broker, it does not matter so much what the cotton is as what the price is. In this line some funny experiences have been mine within the twenty odd years I have been in active cotton-spinning; one in particular, where a treasurer "bought cotton" with the end of his cane. I have seen him go into a broker's office and punch some samples lying on the floor with the end of his cane and buy this or that lot, never feeling of the cotton, only asking, "What country is it?" "What price?" etc. It is perhaps superfluous to add that he "did not believe in the microscope," and yet this man did no worse than many of his fellow-treasurers to-day.

We have followed the cotton fibre through only a few of hundreds of slides, and now I will show you the sections of the cotton fibre from one end to the other of the fibre, or from the seed end to the outer end, and by a minute's looking over the field, you will have no difficulty in seeing all the different shapes of the fibre, in which you can find very many different forms. Here you have the end farthest from the seed, and here you will have a section from about the middle of the fibre; here you have a letter "U," and here another form; in some places it would seem almost as if there were only a single cell, while here you will have a section which plainly shows hundreds of cells, and in a similar direction. A whole evening might be spent upon this single slide, or, perhaps, with this and two or three others, with instruction, and, as a rule, the more we look at the fibre the more interested we become.

We will now look at a well-known muslin, which any lady here would buy at once on the reputation in the market. This photograph is from one of the best known family

muslins in the United States. You will observe that several threads are shown, and I wish to call your attention to the utter lack of "parallelism" in the threads. As a member of the New England Cotton Manufacturers' Association, in Boston, of which I have been a member nearly or quite twenty years, I have heard often long arguments about the parallelism of cotton fibres, etc. There is no more approximation to "parallelism" in the manufacture of cotton fibre than there is in the telephone or telegraph wires of Philadelphia, anywhere in the city, wherever they are, over buildings, on poles or across roofs. And here you can see it, if you will only follow out the fibres in the warp or filling. Please notice, also, all the difference in the size of the different threads, and these are among the actually best products of the loom and spindle in this country. Here we have another view of a piece from well-known mills, in which you will see even greater differences than in the slide which immediately preceded it. You will avoid any tendency to mistake as to warp or filling, observing that the vertical threads are one and the horizontal threads are the other, so that if our spinners present should take exception, it cannot be maintained, because both warp and filling are shown. The "parallelism" of the fibres can be readily seen, whatever there is of it. Here we will take leave of the cotton fibre, with a view of the cotton bales on a railroad depot platform in Georgia. The walk, up which you are looking towards the platform where the bales stand, is the connection with the "steam ginnery," one of the many which are now scattered through the South. Competition in the ginning of cotton has brought about changes which are perfectly ruinous to the cotton-spinner. In 1880, the price was $2 a bale for ginning 450 pounds, putting on jute bagging and the ropes or iron hoops, and the cotton was badly ginned then. More gins were put up, and the price gradually worked down to $1.25 per bale, and even lower than that in some cases, and the cotton was ginned with a vengeance, you may be sure. "Quantity" is the cry, and you never hear "quality." You say, how many bales will a gin do in a day, and if the makers say six, the owner

answers, make it do ten. And the spinner gets the benefit, if there is any to get. This subject will be sometime, in some ginnery, taken up, and radical improvements will be introduced, and perhaps there may be some improved methods of ginning cotton, in which the quality of the côtton fibre will be somewhat of an object. Cotton is now planted by guess, harvested by guess, ginned by the same, without regard to quality, and bought and sold by guess, and I may be allowed, perhaps, to guess that is the reason why some cotton mills do not pay dividends, although the large stockholders keep agents, and in some cases treasurers, in position, at \$6,000 to \$10,000 a year, buying by guess, making by guess, and declaring dividends whenever the officers' salaries are paid, and there is any money with which to do it. In other cases, agents and treasurers are paid \$15,000 a year and the mills make money, keep up their machinery and plant in the best condition, and could, perhaps, do a great deal better if only they had some better way of buying or mixing cotton than by the feeling of an object which is $\frac{1}{1200}$ of an inch in diameter. Suppose a watchmaker should undertake the picking out of a pinion, where the bearings were $\frac{1}{200}$ of an inch different in size, with his fingers; how do you suppose the watch would run, if he happened to pick out one in which the size of the pinion was $\frac{1}{1200}$ of an inch too large? And yet cotton-spinners are doing worse than that every day of the week and every week of the year. I do not make these assertions from theoretical, but from practical connection with the cotton manufacture. My grandfather, my father and myself have been in it ever since 1796, and I may say now, I am probably mixing more cotton to-day for different mills than any other man in the United States; but there is very little hope indeed of any radical change in the methods of the present ginnery. The subject is away ahead of the average manufacturer, because the average manufacturer to-day is not a practical man, but the man who buys cotton knows very little about it, except as it is graded or shipped from such a port or such a place. The cotton interest is one of the largest in this country, as you all know. It is not my

purpose to criticise either the methods or the men who control them, but it is my purpose to present you only facts, which, in my vocation as an engineer, I have been many years learning, to count, measure and weigh facts, and present only facts, not theories. This investigation is from ten to twenty years ahead of the times. Men to-day are too much inclined to hire people for the least dollars, unless they are looking for a president or treasurer, and as the average man can never learn to use a microscope carefully or detect differences in cotton fibre, the microscope is not at a premium in the mind of the average middleman. Yet the fact remains. We are throwing away time and money; our mills are not earning what they might or ought. The cotton-planter is willing to raise better cotton, but the spinner is not ready or willing to pay for it. The cheapest stuff that can be bought for a certain price is what they are all looking for. Trouble among the help is continuous. Poor dividends regular in the most of cases. And where is the trouble? You have seen some of the outlines of the subject, which is great in its outreaching; you can judge for yourselves, and I believe any audience, whether of cotton-spinners, mechanics or otherwise, is intelligent enough to judge of the facts when presented. Very much more might be said, but I have only a few moments before my train leaves, and I must thank you for your courteous attention and kindness. I can truly say that I have enjoyed looking at the slides on the screen this evening, for I have had the best lantern service this evening of any illustrated lecture of the past twelve months.

THE ARMY OF KUKUANALAND.

BY OTHO ERNEST MICHAELIS, Ph.D.,
United States Army.

[*A lecture delivered before the* FRANKLIN INSTITUTE, *March 11, 1887.*]

The Lecturer was introduced by the Secretary of the INSTITUTE, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

I have had many misgivings whether or not the subject of to-night would yield material worth your hearing. That it will not prove unmitigatedly stupid, I hope—relying upon the apparently uniform interest that all good citizens take in military matters, either in vivid narrations of actual experience, or in open discussions of present or future policy. I suppose the majority of my hearers have read Rider Haggard's "King Solomon's Mines," and will recall Allen Quatermain's clear and simple story of the journey to Kukuanaland. You may recollect that in the introduction, Quatermain, recounting the many things upon which he might have dilated, mentions the "most interesting subject of the magnificent system of military organization in force in that country." Ignosi was, you remember, placed, by the aid of Quatermain and his friends, upon the throne, which his bloodthirsty Uncle Twala had usurped. After his thirty years' wanderings among civilized nations, with his quickness of perception, his retentive memory, and his facile adaptability, you may be sure he did nothing to lessen the military ardor and prestige of his people; on the contrary, he taught them all that he believed admirable, the matured results of long experience, observation and reflection. Upon these results, relating both to technical military details and to the broad questions of the relations between the people and the army, I propose to dwell this evening. Kukuanaland has no seaboard, and consequently Ignosi's genius avails us little in assisting to a solution of what is to

us the question of the hour—but it had neighbors to be feared.

You remember that Infadoos told Quatermain, soon after his entrance into the land, "When Twala, the King, calls up his regiments their plumes cover the plains as far as the eye of man can reach." "And if the land is walled in with mountains, who is there for the regiments to fight with?" "Nay, my lord, the country is open there," and again he pointed toward the north; "and now and again warriors sweep down upon us in clouds from a land we know not, and we slay them."

At the battle of Loo, Quatermain had a good opportunity of observing the conduct of the soldiers, of whom he says, and this will give you some idea of the character of the material upon which Ignosi worked, "Never before had I seen such an absolute devotion to the idea of duty, and such a complete indifference to its bitter fruits." In this instance they were "foredoomed to die."

Indeed, in that day, before Ignosi reigned, Quatermain tells us that, "In Kukuanaland, as among the Germans, every able-bodied man is a soldier, so that the whole force of the nation is available for its wars, offensive and defensive."

It is not necessary to give in detail the conversations carried on with the Kukuanian officials, it will suffice to report the conclusions in our own language, and I propose to present to this evening's audience only the more salient features of their military system, such as strike me as possessing general interest.

Considering its extent and population, the standing army of Kukuanaland is very small, but as its strength was fixed by the experienced Ignosi, we must assume that it was large enough for the needs of the country.

Kukuanaland is a land of workers—one person in every three of the whole population has a special trade or occupation; one in every seven is a farmer or stock raiser; one in every 800, a lawyer; one in every 770, a clergyman; one in every 600, a doctor; one in about every 200 is a teacher, and one in every 2,000, a soldier.

"Soldiering" is consequently, in Kukuanaland, a select profession. The term of enlistment is short, three years, the pay is excellent, increasing with length of service; the chances of promotion fair. In case of death in service a liberal pension is provided for dependent survivors. After eighteen years the soldier may retire on half pay; after twenty-four years, on three-quarter pay, and after thirty years, or in case of disability, on full pay.

After one enlistment, honorably terminated, the soldier has the first right to present himself for examination as a candidate for any vacancy occurring in the civil service of the government, for which he has presumable qualification. Soldiers are prohibited from marrying, a wise provision as will be seen, consistent with Ignosi's prominent motive, the maintenance of a natural military spirit among the people, an economical one, as it tends to keep the retired list small; for the natural desire of man for family relations induces many young soldiers to decline re-enlisting after having served one or more terms. One hundred officers are appointed every year, who must all be taken from the army, in compliance with rules and regulations which will presently be mentioned. The age of original enlistment is between seventeen and twenty-two years, excepting for graduates of special schools, who may be twenty-five; all soldiers between these ages are eligible for detail as cadets at the Government Military College, and the selection is entirely dependent upon their own aptitude and application, as determined by annual examination.

As a result, every vacancy in the army is eagerly sought for; the candidates for enlistment being so numerous that the government has been compelled to establish the most rigorous limiting rules.

The privilege of filling a certain number of annual vacancies has been granted to the advanced schools and colleges in the various provinces of the country, whence candidates are accepted on competitive examination. Many bright ambitious young men enlist, not only to gratify inborn military instincts, not only with the hope of promotion, but also to qualify themselves as candidates for civil

positions. Ignosi's wise policy has already borne fruit, for experience has shown that the young man who has the ability, both mental and physical, to serve with credit at least three years in the army, as a rule is a successful aspirant for the civil appointment.

As about one man in every hundred in Kukuanaland is a government employé, it is readily seen that gradually a large available, well-trained military reserve is forming without the slightest additional expense, for all officials must serve in the local reserve, of the formation of which I will say a word in passing.

The country is divided into departments, whose extent is mainly determined by geographical considerations. Each of these departments has its own organized reserve, in which service for three years is compulsory upon all men over twenty-one years of age, not otherwise exempted, and with which, as already stated, all government civil officials must, in time of peace, serve. The reserve is armed, equipped, clothed, and while in practice-encampment, fed and paid by the State. Army officers, line and staff, are detailed, in the various departments, to higher reserve positions, to insure uniformity of drill and methods.

The army is apparently numerously officered, about one officer for every ten men, but when the nature and scope of their duties are considered, the number is not too large.

There is only one way in Kukuanaland to a commission —by enlistment. As a rule the line appointments are made from those soldiers who have successfully passed through the course at the Government Military College, but not infrequently some bright non-commissioned officer will compete successfully for an appointment with the graduates of the school.

The general staff of his army has been a subject of much thought and study with Ignosi. It appears rather large for the mere wants of the standing army, but the King constituted it to meet the requirements of the nation even in case of a great war. Having made wise provision for the constant existence of a strong and available military element among his people, he yet felt that the special and

technical duties, so vitally important for the successful prosecution of war, could satisfactorily be performed only by men professionally competent. Hence the *personnel* of his grand staff was large enough to furnish representatives, in case of war, to all the principal subdivisions of the army, and for the charge of all its main supply and manufacturing depots. While thus able to deal with the affairs of an active army of 1,000,000 of men, its functions, in time of peace, were so directly connected with their welfare, that the people were well content both with the number and rank of the general staff officers.

As with all other branches of the service, these officers are appointed from the ranks after competitive examinations.

To obtain officers for the scientific and technical staff corps, Ignosi has availed himself of the studious and industrial characteristics of his people. Scientific and technological schools are found everywhere in his dominions and their graduates or advanced students, after enlistment and special *military* training at the Government Military College, are examined competitively for positions in the branches of the staff. When vacancies occur, examining boards are appointed in every military department of the country, and those who pass these boards are ordered to Loo, the capital, where a final examination determines the successful candidate.

The *élite* corps in the Kukuanian army is the inspector general's. An assistant inspector is appointed yearly from the captains of the army. The candidates, selected by the primary boards, are finally examined at Loo by a board consisting of the commanding general of the army and the chiefs of the grand staff. As a result, all the captains are ever studying to reach this goal, and the inspectors are consequently the brightest men in the army.

A peculiarity that characterizes the administration of military justice in Kukuanaland is worthy of mention.

There are no courts-martial, such as are familiar to us, except for cowardice, desertion and other capital offenses committed in the presence of the enemy, and for spies

caught red-handed. Judges properly assigned preside at all military trials, and officers constitute the jury, which renders a verdict, following the civil law, by a majority vote. The statutes fix the punishment.

Officers may retire after twenty years total service on half pay; after thirty years, on three-quarter pay; after forty years, they may, and after forty-five years, or in case of disability, they must, retire on full pay. As in the case of enlisted men, liberal pensions are given to dependent survivors. Officers are not permitted to marry before they have been ten years in service. Here again Ignosi has shown his far-reaching wisdom. For most active, exposed service, he has always at command a large body of eager, enthusiastic young men, untrammelled by immediate family ties. The retired list is kept within limits by the numerous resignations of those desiring "to take unto themselves wives," and who, as a rule, at once become applicants for civil appointments, and thus, in most instances, become important factors in the potential government reserve.

Of course my limits this evening are too narrow to permit my entering into a full and detailed account of the manner in which the Kukuanian army is armed, equipped, clothed and fed. This must be reserved for some future occasion. Still, I believe, that a recital of some of the deviations from accustomed ways, well known to you all, together with a brief *résumé* of Ignosi's reasons, be they good or bad, for such deviations, may not prove too great a strain upon your patience and good nature. In his wanderings Ignosi had become fully convinced of the truth of the nineteenth century canon of taste, that the useful must be the beautiful, that the fit, in its simplest form, is most pleasing, and he felt that the sooner the military taste of his countrymen were educated to appreciate the justice of this standard, the sooner they would become imbued with a more exact military spirit, reflexively producing an abler military service. He had seen in older countries famous horse-guard sentinels and their congeners still entrancing the eyes of servant-maids and footmen, he had seen the bright colors and glittering trappings of holiday soldiers

evoke the plaudits, yet want the respect, of crowded streets, and he had seen thousands of earnest men fighting for a principle, as freemen should, without crimson and gold. It was his ambition then to make the Kukuanian soldier a respected working member of a busy community, a man who need not blush because his tools, his clothes, his life were the useful concomitants, the proper exponent of his profession.

As Ignosi had no desire to make the military a class apart, but, on the contrary, to have it considered an essential and appreciated portion of the body-politic, he has been more impressed with the self-voiced personal wants of soldiers, in countries where they were patriotic citizens, endowed with all their rights, duties and feelings, than with the enforced methods of those other countries who maintained great armies for dynastic reasons, where soldiers were considered merely as "food for powder." Ignosi had become convinced that the ideal soldier would work hard, march long, fight well, starve, thirst and go naked, but would not embarrass himself with what he considers unnecessary burdens. He acknowledged that the soldier-citizen would not be a pack mule.

In this respect the soldier's feeling is simply an unconscious evolution of the *Zeitgeist*. Steam, electricity, air, the locomotive, the telegraph and telephone, and the balloon are mighty activities, not changing, but widely extending the underlying principle of all warfare. A battle is an amplified prize-fight. When our modern gladiator stands in the arena, his antagonist establishes himself just beyond arm's length. This idea determines battle formations. The opponents array themselves just beyond the natural range of their weapons. Hence, since the first battle between Hercules and Antæus, the formation distance between combatants has increased directly with the reach of their arms. A line of battle may be likened to a Briareus, his many arms cover all the ground in front, and to the right and left of him, and hence follows not only space between, but also extension of the lines. So to-day, electricity and aëronautics afford the master mind, the commander-in-chief, a practical

coup d'œil, almost illimitable in extent as compared with the *terrain* of former days. Steam gives him the ability to place men and material rapidly where they are most needed. Ignosi recognized this modern condition of warfare, instinctively felt and acted upon by patriotic soldiers, and arrived at the inevitable conclusion, that, all else being granted, *mobility*, power to accomplish long, arduous, *rapid* marching, was the great *desideratum* in the wars of the future. Campaigns would be short and decisive, each having a distinct objective, and supplies in bulk for repair and recuperation, for renewal or continuance of operations, would have to be massed at suitable points, near in time, independently of the operating column. Hence his soldiers carried only their arms and ammunition, a haversack with a capacity of four days' rations, a tin cup able to stand the fire, a combined tin plate and frying-pan, forming a meat can (a Yankee notion), a fork, knife and spoon, a canteen for water, and a hunting-knife.

A soldier thus "outfitted" is before you on the screen. The hunting-knife, of a special design, originating with Lieut. Rodman, of the United States army, is worth dwelling upon for a moment. The shaft is built up of leather washers on the tang, and the blade has the cross-section shown, heavier towards the back, so that it may be handily used for hacking. In combination with the blade it can be utilized in emergency in throwing up effective temporary intrenchments. Carrying burdens is always a disagreeable necessity, and hence everything should be done to make it least irksome. You see here that the chest is left almost unrestricted, and a zinc shoulder-pad has been attached to the haversack and canteen straps to overcome any possible discomfort resulting from their "stringing." Ignosi deemed the fairly accurate judgment of distances as the most important element in military firing. It is a quality that few men can acquire intuitively. He accordingly supplied every individual in his army, officers and soldiers, with telemeters, instruments for determining the distance of an enemy. No complicated mathematical apparatus is practicable, the instrument must be simple in manipulation, and

give instantaneous correct results. He has adopted this simple little device, the invention of Colonel P. Le Boulengé, a distinguished Belgian officer, which gives the distance by noting the time elapsing between the flash and the report of the enemy's fire, and automatically translates this time into yards, as the air-velocity of sound is known. It makes allowance for changes in this velocity with varying temperature, and includes a correction for an average personal equation. The officers carry this little instrument in their pockets, and the men in the buts of their guns. It is here on the screen, where you can also see depicted the method of using the musket telemeter. One additional important use is worth mentioning. By observing the explosion of a shell, its range is determined. The error of the instrument is within the dangerous space of modern weapons. Ignosi has abandoned the bayonet in his army. Still, as a ramrod is a necessity with an arm using metallic ammunition, on account of an occasional failure to extract, he has availed himself of this necessary appendage, and has made it available as a pike. I take pleasure in stating that this ingenious device is due to an American officer, Colonel Buffington. Its method of operation is shown on the screen.

For carrying small-arm ammunition for single-loaders, Ignosi has adopted the Mills cartridge belt—before you. The cartridges are easily taken out of the loops, as you see. The greater portion of the Kukuanian army is supplied with a rapid-firing single-loader, a most excellent weapon, but for two reasons, Ignosi has determined gradually to adopt a repeating gun, one that shall be as good as the best single-loader, and yet, when occasion demands, be an efficient magazine arm. These reasons are, first, in an engagement, a crisis may come when it is of vital importance to deliver a rapid, continuous fire, a veritable *feu d'enfer*, without taking the piece from the shoulder; and, secondly, because in winter campaigns the cold may so benumb the fingers that the handling of single cartridges becomes awkward. When a man pummels you, you must choose one of two possible alternatives, pummel back or run away. So in battle, and I shall have to revert to this idea in speak-

ing of the Kukuanian target practice, men *will fire* at each other, and with modern breech-loaders, even a few minutes' firing entails enormous expenditure of ammunition. The combatant first out of ammunition is apt to reserve further fighting for "another day." Ignosi, influenced by these considerations, concluded that every soldier going into action must carry in immediate accessible shape not less than 150 cartridges. He accomplished this by radically changing the accustomed method of packing. Instead of the usual small boxes holding the cartridges, he substituted endless muslin bands, furnished with fifty "casings," each of which holds a shell, precisely as the belt does. Immediately preceding an engagement, two of these bands are given to each man, who slings them over his shoulder, as you see. This plan also permits the ready supply of the fighting line, by means of pack mules laden with these bands ready for distribution. Ignosi has adopted a detachable magazine gun, apparently the only form of arm that fulfils the condition of being as good as the best single-loader, for it is a single-loader, and yet is, when required, one of the best of repeaters. For the personal carriage of ammunition, he has adopted the same plan as for the single-loader, a magazine belt and magazine bands, as is shown on the screen.

As regards cavalry, Ignosi acted in accordance with conclusions founded upon the general drift of modern experience, and upon the inevitable necessities of future battle formations. The results of experience induced him to consider cavalry as mounted infantry, and the "trooper's" special equipment differed in no respect when mounted from what it was when afoot.

The horse is furnished as a means of rapid transportation, and everything additional carried was intended for *his* comfort, and not for the rider's. Ignosi recalled the telling effect of even small weights upon the animal's endurance, as shown especially in handicap races, and he insisted that the living vehicle should be laden as lightly as possible, hence the horse carried nothing but what was needed for his health, his sustenance, his security, his management, with a single exception to be presently noted. The neces-

sities of future battle formation, by which Ignosi meant, in a word, greatly extended lines, require that the commanding general should have it in his power to hurl a sufficient force rapidly, unexpectedly, upon some exposed point, and therefore Ignosi provided for heavy *mounted* reserves, that could be promptly entered at the weak spot.

As the ordinary carriage of the rifle and reserve ammunition would prove impracticable in such fierce riding as might on occasion be required, Ignosi has adopted the invention of an American cavalry officer, Captain Hunter, and has attached to the saddle, gun and ammunition pockets, as shown on the screen.

A few words on the Kukuanian target practice are in place here. Ignosi had observed that a mark which fired back had a decidedly quickening effect upon the marksman.

As remarked already, fired-at necessitates firing-back, or shelter. Under such circumstances a man must be kept busy; the immediate work at hand is firing his piece, and he will "peg away" as long as his ammunition lasts, and as rapidly as his arm permits. Under such exciting strain, the average soldier will not tarry to assume correct school positions for aiming and firing, he will "blaze away."

Ignosi had seen men, tolerably taught soldiers, firing under excitement, and he had noticed that as far as aiming was concerned, they had apparently recalled the axiom that two points determine a straight line, had drawn a "bead" from the rear sight to the object, and had contentedly fired. The result is shown on the screen. To make certain that at least the muzzle of the gun is presented at the object, Ignosi attached to his arms a small tube as rear sight. You see that if the piece is at all aimed, it must be pointed correctly.

To simulate the excitement, shifting distances, noise and smoke of actual battle, Ignosi provided for practice movable skeleton targets representing advancing lines, which were pushed by small steel-clad traction engines, whose shrieking and puffing gave life to the movement. In addition, each was furnished with a small Gatling, firing blank cartridges, whose sharp reports, by their aggressive sugges-

tiveness, enhanced the value of the practice. Of course he had exact sharp-shooting competitions at long ranges, one feature of which is worth mentioning. No marker was ever exposed during the practice. A bullet-proof shelter was placed in front and to the side of the target. In this the observer recorded the hits by means of a lens and reflecting prism upon a miniature target, which formed part of a *fac-simile* telegraph circuit. The marksman thus saw at once at his side the exact position of his hit.

Ignosi had made artillery a special subject of study; he recognized its predominant importance, for he had seen one of the greatest wars of modern times decided by a superior artillery opposed to a better armed infantry. In his study of this branch of military science, he had been struck by the fact that, with the exception of the recent general introduction of rifled guns, whose superiority had been foretold a century and a half ago, there had been no radical change since the original introduction of cannon as an offensive arm. There had been many changes of detail, necessitated principally by modern improvement in manufacturing processes, but aside from these, in its general aspect, he found the artillery of to-day what it had been in the wars of Frederick and Napoleon. In the equipment of infantry, the great underlying principle of modern warfare had been relentlessly applied, everything that was not absolutely essential had been lopped off, everything had been surrendered for the attainment of the cardinal requisite, mobility. Artillery carriages have been strengthened, guns have been strengthened and are now loaded at the breech, powder has been strengthened, but no emphatic departure from the old system has been obtained.

The complete carriage, the *fourgon*, the wagon that carries the pieces, is to-day in principle what it was when Gustavus Adolphus adopted it. The battery-wagon and forge, one-third of the battery effective, are apparently deemed as necessary to-day, when every campaign condition has changed, as they were during the march to Moscow. He found that the projectiles of to-day, all metal, weather-proof, the powder of to-day so dense as to be almost mois-

ture-repellant, guarded as jealously as when soft wood sabots had to be kept from swelling, as when the loose, absorbent, explosive mixture of the days of yore was cherished as a precious, mysterious, sensitive chemical.

Ignosi had studied the cause of this universal adhesion to traditional requirement. He had endeavored to discover the reason why this most important arm of the service did not progress in sympathy with the *Zeitgeist*, the remorseless pruning spirit of the age. He attributed it to the influence of heredity; he considered it a most remarkable instance of the persistence of ancestral traits. When guns were set up for battle use they were rare and complicated constructions, replacing, not because more simple, but because of greater power, cumbersome mechanical devices, like catapults, whose services required artificers, skilled for the time, and not combatant soldiers. These first cannon occupied fixed positions, as did their prototypes, required equally complicated service, and their attendants were out of the hand-to-hand din of the fight. Ignosi noted that although cannon and arquebuse were almost contemporaneous in development, yet, curiously, their use blindly followed the rule of the bow and the trebuchet. A feudal serf could bend the bow, therefore *he* could use the missile weapon that replaced it. It required science to operate the trebuchet, hence only peculiarly skilled men could be entrusted with its successor, the cannon. For centuries now, by a most marvellous exhibition of transmitted *esprit de corps*, this fictitious distinction has been cherished, and is evidenced to-day in the good-natured tolerance of the artilleryman for his brother-soldier, the "mud-crusher." Of course, the complicated machinery of the middle ages has necessarily disappeared, but for every hampering element "downed," a new one, from Ignosi's point of view, has sprung into vigorous existence. To-day, the development of the capabilities of small-arm fire requires as much science, personal skill, judgment, nerve for its useful application, as does the service of field guns. A plucky fellow can go around the world on a bicycle, carrying his repair material in his pocket, but a four-gun battery, to the reproach of nineteenth-century

military progress, cannot apparently go through a short campaign, without trundling along a village smithy and a country store. Ignosi had looked aghast at the latest tools and stores to be carried in the forge and battery-wagon, every item of which he had been assured was essential. You also have the opportunity—the lists and the note recalls the famous work, "*De omnibus rebus, et quibusnam aliis.*" Yet he had seen such a storehouse on wheels, which had gone through a four years' war, "turned in" with many of the original packages unbroken, explained by the captain's statement that he "had had something else to do than to paint and oil." The old glamour "doth hedge" everything connected with the artillery service, nowhere more pointedly shown than in the mediæval precautions still deemed necessary for the transportation of cartridges and projectiles for cannon, a far simpler problem to-day than the secure carriage of that equally essential element for the usefulness of the command, its supply of sugar. Ignosi was incontestably impressed with the existence of this inherited sentiment by the exhaustive discussions he had heard regarding the proper service of machine guns, the simplest of modern weapons.

An infantry officer is entrusted with fifty or a hundred men, he must teach them to aim, fire and hit, he has numerous and variable personal equations to contend with, he must get his men habituated to the otherwise demoralizing effects of recoil, he must judge distances and correct errors, and his ability to do all this is not impugned. But mount a portion of these same barrels in a rigid frame on wheels, eliminate recoil and personalities, fire them by turning a crank, almost without the possibility of an accident, the successor of the archer must retire, and the descendant of the catapultist take his place. Ignosi determined to break through these trammels of tradition and to bring his artillery in sympathy with the military progress of the age, to make it as mobile as its twin sister, the infantry. He took up the question in detail. (1) He considered the gun-carriage and limber as a wagon, you see a fair exemplar of the usual vehicle on the screen. It is a wagon with a flexible

reach and a rigid pole. Nowhere had he found such another construction. In all his wanderings he had never met a four-wheeler in which these conditions were not exactly reversed. Every wagon he had seen had a rigid reach and a hinged pole. As this was the universal method Ignosi adopted it. He had heard artillery officers complain of the vertical "thrashing" of the pole as destructive to their horses, many ingenious plans had been suggested for the amelioration of this evil, none of which, however, struck at its root. Its cause is easily understood; the limber wheels meet an inequality and are checked; the rigid pole, owing to the pressure of the trail, goes up, the carriage wheels next strike, the trail goes up and the pole down, to the great discomfort of the horse. Hence, in travelling over rough ground, there is a constant scissors-like opening and shutting between carriage and limber, transmitted, of course, in an increased ratio, to the end of the pole.

Yet, as artillery carriages cannot choose their roads, there must be *give* in the construction, customarily obtained in every-day practice by springs.

Furthermore, there must be a simple means of rapidly converting the gun-wagon into a gun-carriage, adequate to sustain the piece in firing. These two essential conditions have for centuries been well met by the established lunette and pintle connection, a strong junction, yet affording an easy, quick and simple means of disjoining limber and carriage. Because it fulfilled these necessary requirements so satisfactorily, this joint has maintained itself to the present, notwithstanding that when it is considered a part of a gun-wagon, it violates the elementary principle of teaming, a virtually stiff connection between front and hind wheels. A rigid pole is a logical sequence of a hinged reach, for in this case, as seen, there is no other provision for keeping the limber body horizontal, nothing else to prevent its continuous "wobbling" up and down. Ignosi formulated the essential qualities which his carriage must possess thus:

A rigid reach; a hinged pole; a universal joint arrangement, replacing the fifth wheel and springs of ordinary vehicles; a sure method for rapidly limbering and unlimbering.

It would consume too much time to describe in detail how he accomplished this—a model is before you, and the construction is shown on the screen. The reach is rigid vertically, movable horizontally, the limber "drawhead" can revolve, the pole is hinged vertically, the three together operate as a universal joint. The pintle is long enough to afford an instantaneous connection should circumstances demand it.

Mobility requires rapid manœuvring. The latest carriage has a turning angle of 55°—Ignosi's a normal turning angle of 90°, an emergency angle of over 100°. To attain this desirable end, Ignosi abolished the pintle hook and substituted a "drawhead," suggested by universal railroad practice. Usually this is checked by chains, yet allowing the spring to act slightly—thus saving many a shock to the horses. In actual combat the chains are unhooked, thereby giving the spring full play.

As the "drawhead" had to be long, it required support. Ignosi upheld it accordingly in the familiar manner, by a truss, as you see. But this interfered with the carriage of the time-honored ammunition chest, so Ignosi gave it up. He adopted an ammunition box, holding three rounds, weighing about fifty pounds, with cover cleverly fastened, as you can see, a device due to Colonel Williston, of the American artillery. Sixteen of these packing-boxes, forty-eight rounds, a greater number than are generally carried, are placed on the limber, and are lashed, if necessary, just as any other load would be. The cartridges are packed in paper bags, perfectly water-proof, hermetically sealed, and easily torn off in action. Ignosi designs that these boxes should also replace the pouches used in carrying the ammunition to the gun.

When the limber becomes a two-wheeler, the simple device shown on the screen, a movable sleeve, locks the pole, and it may gallop off for further supplies, or be used as any cart might. A permanent seat is available for the cannoneers, and capacious receptacles are gained, in which everything necessary for casual repairs is carried, all without important change of dimensions, thus enabling him

to dispense entirely with the ancient forge and battery-wagon. For the rare cases in which a forge may be deemed desirable, Ignosi had adopted the miner's pattern, modified by Colonel Whittemore, and, as here shown, it is readily stowed in the limber boot. The occasions for its use in Kukuanian campaigns will be rare, for "cold shoeing" is an assured success, mild steel has replaced iron, and Ignosi has adopted the Clarke type of wheel, shown in model and on the screen, which can be "knocked down" and assembled without the aid of wheelwright or blacksmith, making the replacing of a broken felloe or spoke a very simple matter.

Ignosi had seen the destructive effects upon the carriage of the severe recoil strains due to modern light guns, long projectiles and heavy charges—this he endeavored to overcome by the device shown in model and projection, a recoil jacket, in which the gun moves, very much as the piston-rod does in the cylinder.

The spring "takes" the initial shock, and thus saves the carriage.

Ignosi placed the machine gun in the same category as the revolver; for offensive purposes he considered it the weapon of the instant. He adopted the latest Gatling with the Accles positive feed, rendering it available for fire at any angle.

As this gun can fire 1,200 rounds per minute, to make it an integral factor of an advancing line would require an amount of ammunition impracticable to carry with it. Hence Ignosi, while recognizing its great value for *defensive* purposes, each piece virtually representing under these circumstances a full company, did not deem it a feasible element in the engaged line of battle. His reserve, however, was plentifully supplied with Gatlings, each gun fully equipped with 3,600 rounds, *ready for use;* in other words, with thirty-six charged Accles drums, equivalent to three minutes' furious volley firing. He appreciated that in every great battle a moment might come in which a far-seeing commander, by a rapid concentration of aggressive force, without laying bare any portion of his main line, might, by the *coup de main*, overwhelm the enemy. And for this pur-

pose he deemed the machine gun a valuable auxiliary *offensive* weapon.

The clock warns me that I must afford release to your compulsory attention, else I would dwell upon the many other changes made by Ignosi. I would like to describe, for instance, his artillery harness, planned upon that used with steam fire-engines; to tell you how he got rid of the destructive punching and cutting of straps to make them fit; to dwell upon his barracks, his mess outfits, his simple methods of obtaining and accounting for repair material. I would like to go into details regarding the kind and quality of clothing used, to indicate the methods by which he secured unadulterated, unrobbed food for his men. But time forbids; I shall only add that he believed thoroughly that practical *ways* used and approved by the community at large must be good, and he therefore made it a fixed rule to apply them to the army *methods*.

The knowledge he had gained by his own experience, his method of gaining it, by friendly intercourse with keen thinkers, by constant, intelligent observation and examination of what the workers—they who strive hard for necessary profit—do, he grafted upon the military system of his country.

To us, Ignosi is an iconoclast. He has broken the idols of the fathers; he has dissipated the traditions of the ages; he has extirpated the last vestige of feudalism, and he has made the Army of Kukuanaland, of the people, for the people, loved, honored, *respected* by all.

EXPERIMENTS MADE AT THE NEW YORK NAVY YARD, TO DETERMINE THE RELATIVE ECONOMIC EFFICIENCY, IN PROPORTION OF WEIGHT OF STEAM USED TO WEIGHT OF WATER LIFTED, OF A *RECIPROCATING-PUMP*, A *ROTARY-PUMP*, AND A *STEAM SIPHON-PUMP*, ALL THREE BEING AUXILIARY STEAM-PUMPS FOR VESSELS, AND RAISING WATER TO THE SAME HEIGHT.

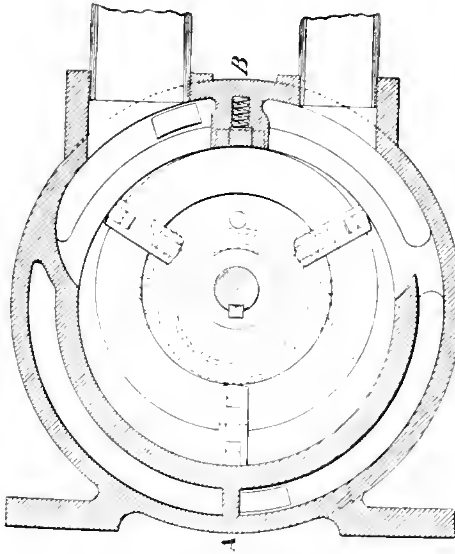
BY CHIEF ENGINEER ISHERWOOD, U.S.N.

The following experiments were made under the direction of the writer at the New York Navy Yard during the months of March and April, 1867, to ascertain the weight of water lifted through a given height per pound weight of steam expended, by means of a reciprocating-pump, a rotary-pump, and a steam siphon pump. The reciprocating and rotary-pumps were constructed for auxiliary steam pumps on board steamers, to pump water into and out of the boilers, and also from the vessel overboard. The siphon pump was constructed for the latter purpose only. The experiments were conducted, and with the utmost accuracy, by First Assistant Engineer Clark Fisher, U. S. N.

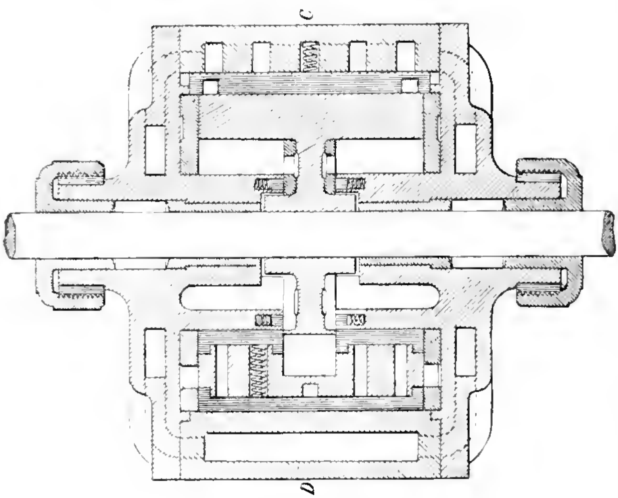
DESCRIPTION OF THE PUMPS.

The *Reciprocating-Pump* used is known as "The Woodward patent improved safety Steam-Pump and Fire Engine." It is of the No. 4 size. The steam cylinder is 9 inches in diameter and the stroke of its piston is 6 inches. The diameter of the steam piston-rod is $1\frac{3}{4}$ inches, making the average net area of the piston for a double stroke 62·414 square inches. The cylinder is horizontal, and uses the steam without expansion and without condensation. The steam-valve is an ordinary three-ported slide, and is worked by an eccentric on the fly-wheel shaft. The water cylinder or pump is 5 inches in diameter and has a 6-inch stroke of piston, the rod of which is $1\frac{3}{4}$ inches in diameter, being a direct prolongation of the

rod of the steam piston. The average net area of the pump piston for a double stroke is 18·433 square inches, being to that of the steam piston in the ratio of 1·000 to 3·386. The steam cylinder, pump cylinder, and fly-wheel shaft pillow-blocks, are supported upon a horizontal cast-iron foundation-plate, to which they are bolted, the axes of all three being in the same horizontal straight line. The fly-wheel shaft is cranked between its pillow-blocks, and is revolved by an open connecting-rod, articulated to the crank-pin and to two cross-head journals supported by the piston-rod of the steam cylinder and pump, and working between them. One part of the connecting-rod works on one side of the pump, and the other part on the other side; these two parts are connected by a cross-piece lying between the pump and the fly-wheel shaft, and at the centre of this cross-piece is the stub-end of the connecting-rod attached to the crank-pin by brasses, secured with a strap and key. The fly-wheel is overhanging on one side of the foundation-plate, and the eccentric is overhanging on the other side. The pump is provided with a large air-chamber. The suction or receiving-pipe of the pump was $2\frac{3}{4}$ inches in inside diameter, and 3 feet 7 inches in length. Its cross area was 5·939 square inches, or in the ratio of 1·000 to 3·103 of the pump piston. The discharging-nozzle was of the same inner diameter, namely $2\frac{3}{4}$ inches, but, for the purpose of the experiment, the discharging-pipe bolted to it was of only $1\frac{1}{2}$ inches inner diameter, giving a cross area of 1·767 square inches; the length of this pipe was 28 feet. From the above figures, the mean velocity of the water in the pump and in the discharging-pipe compares as 1·000 to 10·432. The reason why the diameter of the discharging-pipe was made only $1\frac{1}{2}$ inches instead of $2\frac{3}{4}$ inches, as intended by the pump maker, was to secure a comparison with the results given by the rotary-pump, the discharge orifice of the latter being $1\frac{1}{2}$ inches in diameter, as intended by its maker. The reduction, however, of the diameter of the discharging-pipe was unfair to the reciprocating-pump, as it produced a greater pressure on its piston than if the intended diameter had been used. Each pump should have been used with its



Section on *C D*.



Section on *A B*.

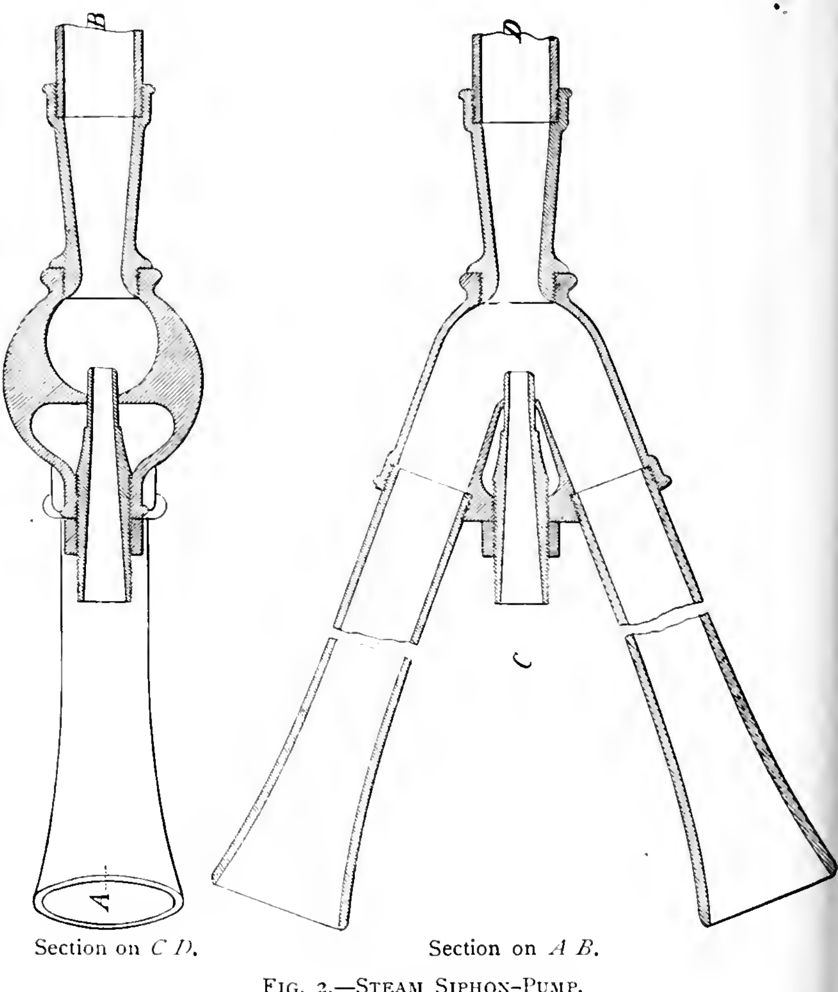
FIG. 1—ROTARY-PUMP.

proper diameter of discharging-pipe, namely 1½ inches for the rotary-pump, and 2¾ inches for the reciprocating-pump. These two types of pump require different diameters of discharging-pipe for the delivery of equal quantities of water in equal times, as the discharge from the rotary-pump is continuous and uniform, while that from the reciprocating-pump is intermittent and irregular.

The *Rotary-Pump* (*Fig. 1*) has a cast-iron cylindrical shell, with the proper water-cavity and water-passages. The two ends are cast separately from the cylindrical shell, and have water-passages communicating with those of the latter. A wrought-iron spindle, with stuffing-boxes, passes through both ends, and gives motion to a cast-iron hub revolving within the water-cavity. The axes of this hub and of the water-cavity do not coincide, the hub being eccentric to the cavity, and the point where they touch is made water-tight by a brass packing-ring set out with screws. On one side of this point the water is received through a pipe of 2 inches inner diameter, and on the other side it is discharged through a pipe of 1½ inches diameter. The ends of the cavity are lined with brass. Within the revolving hub are fitted three equidistant rectangular pistons, which are free to move radially, that is, in direction from the centre of the hub or axis of its spindle. These pistons form with each other angles of 120 degrees, and their outer edges are kept in contact with the periphery of the cavity by brass packing-strips set out with springs. For tightness against the ends of the cavity these pistons depend on the precision of their fitting-up. As the hub revolves, the three pistons are carried around with it, moving at the same time radially in and out, so as to remain in contact with the periphery of the cavity notwithstanding the eccentricity, and thus they force the water before them, and receive it into the vacuous space left behind them. This system requires no valves, and produces a continuous and uniform discharge. It is not a centrifugal-pump, and is as positive in its action as the reciprocating-pump. The diameter of the water-cavity is 7 inches, and its breadth is 5 inches. The pump pistons displace per revolution 109 cubic inches by calculation.

The suction or receiving-pipe was 5 feet 5 inches long; the discharging-pipe was 28 feet long.

The rotary-pump was operated by the same steam cylinder which worked the reciprocating-pump. The latter having



Section on *C D*. Section on *A B*.

FIG. 2.—STEAM SIPHON-PUMP.

been disconnected from its steam cylinder, a 3 inches wide belt was carried from the fly-wheel to a pulley on the spindle of the rotary-pump; the diameters of the fly-wheel and pulley compared as 2·3 to 1·0, consequently the pump made

1·15 revolutions to each single stroke of the steam-cylinder piston.

The Steam Siphon-Pump (*Fig. 2*) is simply one of the many applications of Giffard's "Injector." It is composed as follows: Into the lower part of a hollow brass sphere of $5\frac{3}{8}$ inches outside diameter, are screwed obliquely two suction or receiving pipes of 2 inches internal diameter, their axes making an angle with each other of 42 degrees. Between these pipes, and having its axis in the same plane with their axes, is screwed a nozzle for the steam-jet; this nozzle intrudes into the sphere, and its upper end is one-third of an inch above the centre of the sphere; its lower end protrudes below the sphere. The nozzle forms the frustum of a cone, with inner diameter at the base of $1\frac{1}{4}$ inches, and a height of $6\frac{3}{4}$ inches; and to this base, or lower end, is screwed the steam-pipe. Immediately over this nozzle, and having its axis in the same straight line with the axis of the nozzle, there is screwed into the sphere a nozzle for the discharging-pipe; this discharging-pipe nozzle is an inverted frustum of a cone, the lower inner diameter of which is $1\frac{1}{8}$ inches, and the upper inner diameter 2 inches; the height of the inverted frustum is $4\frac{1}{2}$ inches, and into its upper end is screwed the discharging-pipe, 2 inches in internal diameter and 22 feet in length. During the three trials with the siphon-pump, three different nozzles for the steam-jet were used; they all had the same height of $6\frac{3}{4}$ inches, and had the same inner lower diameter of $1\frac{1}{4}$ inches, but the upper inner diameter was respectively $\frac{3}{4}$, $\frac{5}{8}$ and $\frac{9}{16}$ inch, according as the trials were made with steam of 20, 30 and 40 pounds per square inch above the atmosphere in the boiler. The vertical height between the top of the steam-jet nozzle and the bottom of the discharging-pipe nozzle was 3 inches; and the top of the steam-jet nozzle was 54 inches above the lower level of the water lifted. With this system of pump there was, of course, neither valves nor piston, and the water discharge was as continuous and uniform as the steam supply.

The pipe supplying steam from the boiler was 20 feet 6 inches long and $1\frac{1}{2}$ inches in inner diameter. It was thoroughly covered with felt.

All three pumps were furnished and adjusted by their makers for these trials.

MANNER OF MAKING THE EXPERIMENTS.

The boiler, tanks and pumps employed in the experiments were situated in a closed wooden shed, and well protected from the weather. The steam was supplied by a small boiler placed adjacent to the pumps and used entirely for the purposes of the experiments.

The feed water was pumped into the boiler by a small auxiliary steam pump, which drew it from a wooden tank, lined with sheet lead. This tank was filled, by gravity, from the Navy Yard hydrant, and the feed water was accurately measured in it before being pumped into the boiler. The exhaust steam from the auxiliary steam pump was discharged through a coil of pipe placed in a small cistern, kept filled with cold water from the hydrant for the purpose of condensing it, and was discharged in the form of water, back into the feed-water tank. By this arrangement the weight of water measured in the feed-water tank correctly represented the weight of steam used by the steam cylinder working the reciprocating-pump and the rotary-pump, notwithstanding that the auxiliary steam pump was worked with steam from the same boiler.

Previously to commencing an experiment, all the tanks, the pumps and their connexions, and the boiler, were thoroughly examined for tightness against water leakage; the pumps and boiler were tested under the maximum steam pressure. The boiler and steam-pipes were well covered with felt, but the steam cylinder, working the reciprocating and rotary pumps, had no non-heat-conducting protection.

The supply-tank, from which the water was lifted, was of plate iron, and rested on the floor of the shed. It was filled, by gravity, partly from the Navy Yard hydrant, but chiefly from the receiving-tanks, and the filling was maintained, by the more or less opening of cocks, at such a rate as to keep the surface of the water at a fixed level while the pumps were lifting it. The water was lifted to a vertical height of 17 feet 8 inches, through a discharging-pipe of

1½ inches inner diameter, the length of which for the reciprocating and rotary pumps was 28 feet, and for the steam siphon-pump 22 feet. The discharging-pipe delivered the lifted water for measurement into two receiving-tanks alternately, the one tank being filled while the other was being emptied, and so on. These tanks were of wood, lined with sheet lead, and each contained exactly 160 cubic feet of water, being graduated to precisely that capacity by an overflow-pipe. They were situated, side by side, on an elevated platform, with their bottoms carefully leveled, and were filled over their top edges. At the centre of the bottom of each was a stop-cock, and from it a pipe discharged, by gravity, the contents of the tank either into the supply-tank or into an outside drain.

As the weight of feed water pumped into the boiler was the exact measure of the cost of lifting the water in the different experiments, and as it was essential to the correct making of these experiments that the boiler pr ssure and position of the throttle-valve should remain constant during each, which could only be effected by the opening or closing of the furnace-door, thereby rendering the weight of coal consumed an inaccurate measure of the cost and of no value in ascertaining the results, the weight of coal consumed has been omitted in the table containing the data of the experiments.

The experiments with the reciprocating and rotary pumps continued seventy-two consecutive hours each, but with the siphon-pump there were made three experiments, each of twenty-four consecutive hours, in order to ascertain the effect of working it with steam of different pressure, namely, of 20, 30 and 40 pounds per square inch above the atmosphere. During each experiment, the conditions were allowed to vary as little as possible. The assistant engineers, four in number, and their attendants, were arranged in watches of six hours each. At the end of every hour, there were recorded in a tabular record, by the engineer of the watch, the average temperature, in degrees Fahrenheit during that hour, of the external atmosphere in the shade, of the interior of the shed, of the water in the sup-

ply-tank before it was lifted and of the same in the receiving-tank after it had been lifted, the average height of the barometer and the average steam pressure per gauge in the boiler in pounds per square inch above the atmosphere. In other columns were recorded the number, per counter, of single strokes made during the hour by the steam piston and pump piston of the reciprocating-pump, the number of single strokes made by the steam piston operating the rotary-pump and of revolutions made by the piston of that pump and the number of pounds of feed water pumped by the auxiliary steam pump into the boiler, weighed into the tank used for that purpose. The exact time at which each receiving-tank was emptied was also noted, and, at the end of each experiment, the water in the boiler was left at precisely the same height in the glass water-gauge as at the commencement, and with the same steam pressure upon it.

The data and results of the experiments will be found in the following table, in which, for facility of reference, the quantities are grouped and the lines containing them are numbered, but previous to discussing them an explanation of the quantities will be given.

EXPLANATION OF THE TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE WITH THE RECIPROCATING, ROTARY AND SIPHON PUMPS.

Line 1 gives the time at which each experiment commenced.

Total Quantities.—Line 2 contains the duration of each experiment in consecutive hours.

Line 3 contains the number of cubic feet of water of the temperature on line 23, lifted through the height of 17 feet 8 inches. This quantity was obtained by measurement of the water in the two receiving-tanks.

Line 4 contains the number of pounds of water lifted through that height. It is obtained, for the experiments with the reciprocating and rotary pumps, by multiplying the quantities on line 3 by the weight in pounds of a cubic foot of water of the temperature on line 23, and, for the experiments with the siphon-pump, by multiplying the

quantity on line 3 by the weight in pounds of a cubic foot of water of the temperature on line 23, and adding thereto the quantity on line 5. The weight of water lifted by the steam siphon-pump is evidently not only the weight lifted from the supply-tank, but also the weight of feed water (line 5) pumped into the boiler. Of course, when the siphon-pump is employed for pumping out the hold of a vessel or similar work, the commercially valuable work done is simply the weight of water lifted, exclusive of the steam condensed in the lifting. The whole of the steam consumed by the siphon-pump is liquefied by the water lifted, and the aggregate weight of the two is delivered into the receiving-tank.

Line 5 contains the number of pounds of feed water pumped by the small auxiliary steam pump into the boiler. This water was weighed hourly into the tank from which the pump drew it, and gives the weight alone of steam consumed in the different experiments for lifting the water from the supply to the receiving tanks, but not for feeding the boiler.

Line 6 contains the number of single strokes made by the piston of the steam cylinder which operated the reciprocating and rotary pumps. The steam cylinder was, of course, double-acting.

Line 7 contains the number of single strokes made by the piston of the reciprocating-pump and of revolutions made by the piston of the rotary-pump. The reciprocating-pump piston was double-acting, and, of course, made stroke for stroke with the steam-cylinder piston. The rotary-pump piston made 1·15 revolutions to each single stroke of the steam-cylinder piston, being geared up by belt and pulleys with diameters in the ratio of 1·0 to 2·3; that is, the pump piston made 2·3 revolutions to each double stroke of the steam-cylinder piston.

Steam Cylinder.—Line 8 contains the number of single strokes made per minute by the piston of the steam cylinder which operated the reciprocating and rotary pumps. It is the quotient of the division of the quantity on line 6 by 4,320, the number of minutes the experiments lasted.

Line 9 contains the number of single strokes made per minute by the piston of the reciprocating-pump and of revolutions made per minute by the piston of the rotary-pump. It is the quotient of the division of the quantity on line 7 by 4,320.

Line 10 shows the average pressure during the experiment of the steam in the boiler, in pounds per square inch above the atmosphere.

Line 11 shows the position of the throttle-valve; it remained unaltered during each experiment.

Line 12 shows the average height of the barometer in inches of mercury.

Line 13 shows the estimated mean total pressure on the steam piston in pounds per square inch above zero. This was not obtained by direct measurement, but was estimated in the following manner: The reciprocating-pump was run at the experimental speed of 218⅔ single strokes per minute, with the throttle-valve wide open, and the boiler pressure was allowed to regulate itself under these conditions. It was found to be 20 pounds per square inch above the atmosphere. From this there was deduced that the average mean pressure in the steam cylinder for the whole stroke of the piston would be 4·8 pounds per square inch less, or 15·2 pounds per square inch above the atmosphere, making, with the atmospheric pressure (line 12) of 14·8 pounds per square inch, 30·0 pounds.

Line 14 contains the estimated back pressure, which would be the atmospheric pressure of 14·8 pounds per square inch, and something more to expel the steam into it from the cylinder; that something more was assumed to be 0·7 pound per square inch, making the total back pressure resisting the movement of the steam piston 15·5 pounds per square inch above zero.

Line 15 contains the estimated mean gross-effective pressure on the steam piston in pounds per square inch. It is the quantity remaining after subtracting from the quantity on line 13 the quantity on line 14.

Line 16 contains the estimated pressure in pounds per square inch required to work the steam piston and its

attached pump, *per se*, that is to say, without the load, or with the water in the supply-tank shut off.

Line 17 contains the estimated net pressure on the steam piston in pounds per square inch. It is the pressure devoted solely to the lifting of the water from the supply to the receiving-tank.

The object of these estimated steam pressures in the cylinder is to obtain a reasonable approximation of the relation which the total pressure employed in the cylinder bears to the pressure utilized, and consequently an inference as to how economically the total steam pressure was used. Now we find that out of a total pressure of 30 pounds, and for which fuel had been consumed *pro rata*, only 13 pounds were utilized, or $43\frac{1}{3}$ per centum. This was due, however, to the unnecessarily large size of the cylinder, and to the fact that the steam was used without condensation, whereby the back pressure was more than the atmospheric pressure. Had the cylinder, while doing the same work, been of the proper size to have worked with steam of 30 pounds per square-inch boiler pressure, and a wide open throttle, the mean total pressure on the piston would have been 40 pounds per square inch, and the back and friction pressures remaining constant (17 pounds per square inch of piston) the net or useful pressure would have risen to 23 pounds per square inch, or $57\frac{1}{2}$ per centum. Under these circumstances the weight of steam expended to do the same work, would have been decreased in the inverse ratio of $43\frac{1}{3}$ to $57\frac{1}{2}$, that is would have been in the case of the reciprocating-pump, only 18,082 pounds instead of the 23,993 pounds;[1] the steam being used, as in the experiment, without condensation and without expansion.

Lines 18, 19 and 20, contain the estimated total, gross-effective, and net horse-power developed by the steam cylinder, corresponding respectively to the piston pressures on lines 13, 15 and 17, and to the piston speed due to the number of its single strokes as given on line 8.

It has already been explained how the piston pressures on lines 13, 15 and 17 were obtained in the case of the reciprocating-pump, and how from them resulted the horse

power on lines 18, 19 and 20; but, in the case of the rotary-pump, these pressures and powers were differently obtained. As the steam cylinder was the same with both pumps, and as the velocity of the piston, and the pressures upon it, could not have materially differed, it is obvious that for correct comparison the weight of feed water (line 5) consumed in the two cases would represent accurately the relative *total* horse-power developed by the cylinder, as that power expresses the *entire* dynamic effect produced by the steam, including overcoming the back and friction pressures and the resistance of the water load, etc. Hence, the total horse-power in the case of the rotary-pump (6·715) have been obtained from the total horse-power (6·204) in the case of the reciprocating-pump, by the simple proportion of 23,993 : 6·204 :: 25,970 : 6·715. The total horse-power once known, the total piston pressure (line 13) due to it was easily calculated, and as the back pressure (line 14) and friction pressure (line 16) must have been the same, with the rotary-pump as with the reciprocating-pump, the gross-effective pressure was the remainder after their subtraction from the total pressure. From these pressures the gross-effective and net horse-power developed by the steam piston were calculated as before.

Temperatures.—Lines 21 and 22 show the average temperature in degrees Fahrenheit, of the external atmosphere in the shade, and of the interior of the shed, during the experiments.

Lines 23 and 24 show the average temperature in degrees Fahrenheit, of the water raised, both before being raised when in the supply-tank, and after being raised when in the receiving-tank. These temperatures are the same in the cases of the reciprocating and rotary pumps, but differ in that of the siphon-pump, owing to the heat communicated to the water by the steam in its condensation.

Duty.—Lines 25 and 26 show the duty performed by the consumption of one pound weight of steam in the cases of the three pumps. By "duty" is meant the net or useful effect produced per unit of cost, which in these cases, on line 25, is the weight of water lifted per pound weight of steam

from the supply-tank to the receiving-tank; including for the rotary-pump the additional weight of feed water pumped into the boiler (line 5), and on line 26 it is the weight of water raised one foot high per pound weight of steam expended.

Pumps.—Line 27 shows the number of cubic inches of water actually discharged by the reciprocating-pump per single stroke of its piston, and the number of cubic inches of water actually discharged by the rotary-pump per revolution of its piston. These quantities were obtained by dividing the number of cubic inches of water lifted (obtained from the number of cubic feet on line 3) by the number, respectively, of single strokes made by the reciprocating-pump piston, and of revolutions made by the rotary-pump piston (line 7).

Line 28 shows the number of cubic inches of space displacement of the piston of the reciprocating-pump per single stroke, and the number of cubic inches of space displacement of the piston of the rotary-pump per revolution. Had the pumps completely filled, these capacities would have represented the quantity of water discharged per stroke and per revolution per piston.

Line 29 shows the fraction which the quantity on line 27 is of the quantity on line 28.

DISCUSSION OF THE RESULTS.

Siphon-Pump.—The name of siphon-pump, given to it by its manufacturers, is evidently a misnomer, as there is no siphon action whatever involved. This pump is simply a steam injector and operates on that well-known principle.

In these experiments it was found that with the proportions used, the siphon-pump operated very imperfectly with boiler steam of 20 pounds per square inch above the atmosphere, and that it would not operate at all with a less pressure. Even with the 20 pounds, it required constant watching, stopping about once an hour with heavy concussions similar to those made by blowing steam from a marine boiler through the bottom of the vessel. When thus stopped, a pressure of 25 pounds was required to start

the pump, besides cooling the pump-chambers by forcing cold water down the discharging-pipe, and applying it to the outside of the same. With the 20 pounds pressure the temperature of the supply water could not be carried higher than 60° F.

When the steam pressure was raised in the boiler to 30 pounds per square inch above the atmosphere, the pump worked perfectly, as it also did at the higher pressure of 40 pounds, beyond which the strength of the boiler would not permit the pressure to be carried. With these pressures the highest temperature practicable for the feed water was 68° and 71° F., respectively.

It will be observed there were three experiments made with the siphon-pump, the steam in the boiler being carried respectively at 20, 30 and 40 pounds per square inch above the atmosphere. As the pump worked satisfactorily in the last two cases only, and as the economic result or duty varied in them but a trifle, the mean of those two will be taken for the correct performance. This duty was $\left(\frac{660{\cdot}355 + 661{\cdot}811}{2} =\right)$ 661·083 pounds of water raised one foot high by the expenditure of one pound weight of steam. As this duty includes the weight of steam itself expended in producing it, it represents the entire dynamic effect produced by the steam. The highest temperature practicable for the water in the supply-tank was 70° F., and the temperature of the same when delivered into the receiving-tank was 100°.

As the experiments were for the purpose of determining only the cost in weight of steam consumed in lifting water, the increased temperature given to the water lifted by the siphon-pump does not enter as an element in the comparison of the economic performance of that pump with the economic performances of other pumps. The water lifted was heated about 30° F., by the process of lifting it, and whenever such heating is of utility, its commercial value must be included in estimating the comparative performance of the pump. The exhaust steam, however, from the cylinders driving the reciprocating and rotary pumps, could be used

for the same heating purpose, but would require additional and especially adapted mechanism, thereby increasing the money cost of those pumps.

Reciprocating-Pump. The duty with the reciprocating-pump, under the actual conditions of the experiment, was 2397·001 pounds of water raised one foot high by the expenditure of one pound weight of steam, or $\left(\frac{2397 \cdot 001}{661 \cdot 083} =\right)$ 3·626 times greater than that of the siphon-pump, including with the latter the pound of steam itself. It will be recollected, however, in this case, that the steam was used without expansion, and with so high a back pressure that, taken in conjunction with the friction pressure, there was utilized of the total pressure only $43\frac{3}{5}$ per centum. Let us suppose, however, that the steam had been used with the same boiler pressure of 30 pounds per square inch above the atmosphere, but with condensation, the back pressure being 3·5 pounds per square inch above zero, and the friction pressure 1·5 pounds per square inch of piston, the steam being cut off at 0·6 of the stroke of the piston from the commencement, then the total indicated horse-power, with a very small steam cylinder, would be obtained for about 40 pounds o steam per hour. The mean total pressure would be abou 38 pounds per square inch above zero, of which (3·5 + 1·5 = 5 pounds would be neutralized by the back and friction pressures, leaving 33 pounds utilized, or $86\frac{4}{5}$ per centum. As the total horse-powers developed were 6·204, at 40 pounds of steam per hour each, the consumption of steam would have been 248·16 pounds per hour, or 17,867·52 pounds for the seventy-two hours of the experiment, instead of the 23,993·00 pounds actually consumed; and the duty, instead of being 2397·001 pounds of water raised one foot high per pound weight of steam, would have been 3218·760 pounds, or $\left(\frac{3218 \cdot 760}{661 \cdot 083} =\right)$ 4·869 times greater than that of the siphon-pump, including with the latter the pound of steam itself. Where the economy of fuel is of the slightest importance, it is evident that any competition of the siphon-pump with the reciprocating-pump is hopeless. The former can only be used

advantageously on board a steamer to pump out its bilge after the vessel has just come to anchor, with steam in the boilers; or when the vessel has struck and there is no further use for the main engines. It is very cheap in first cost, cannot become deranged, requires neither attention, adjustment nor repairs, and can be placed wherever there is room for a pipe of a few inches diameter.

A reference to line 29 of the table shows that the water discharge of the reciprocating-pump at each stroke of its piston was 0·864 of the space displacement of that piston per stroke, consequently 0·136 of that space displacement remained unfilled. The speed of the piston of the pump was only 109⅓ feet per minute. The receiving-orifice was large and the receiving-pipe short. The valve, the joints, and the stuffing-box were in complete condition and very tight, having been put in order by the maker and patentee especially for this trial. The 0·136 of the space displacement of the piston stroke unfilled by water must have been filled by air evolved from the water entering the pump under less than the atmospheric pressure, and leaking through the joints and stuffing-box. Part of the water deficiency was also doubtless due to water leakage past the piston and delivering valves, and by regurgitation past the receiving-valves.

Rotary-Pump. A single glance at the quantities on lines 25 and 26 of the table is sufficient to show the marked inferiority of the rotary-pump to the reciprocating-pump under the experimental conditions. The duty given on those lines is for the consumption of one pound weight of steam from the boiler, which would have correctly represented the cost of the pumping relatively to that of the reciprocating-pump, had the same pressures been used in the steam cylinder. These pressures however were not the same, the mean total pressure (line 13) being less with the rotary-pump than with the reciprocating-pump, while the back and friction pressures (lines 14 and 16) remained constant; hence, there was a less proportion of the total pressures utilized with the rotary-pump than with the reciprocating-pump. On this account the net horse-

Table containing the data, to determine the relative economic efficiency, in proping-pump, a rotary-pump and a steam siphon-pump, all tl

Number of Line.			Steam Siphon-Pump. Two receiving-pipes, each 2 inches internal diameter and 40 inches long. One discharge-pipe, 2 inches internal diameter and 22 feet long. The centre of the pump or mouth of steam-jet is 54 inches above the surface of the water in the supply-tank. Steam-pipe, from boiler to pump, 1½-inch internal diameter, 20½ feet long, and telted.		
			Steam-jet nozzle, ¾-inch in least inner diameter, used with steam of 20 pounds per square inch pressure above the atmosphere, which was the least pressure with which the pump would work, and even then very imperfectly, stopping about once an hour, with heavy concussions, and requiring the pump chambers to be cooled before again starting.	Steam-jet nozzle ⅝-inch in least inner diameter, used with steam of 30 pounds per square inch pressure above the atmosphere. Pump working perfectly.	Steam-jet nozzle, 9/16-inch in least inner diameter, used with steam of 40 pounds per square inch pressure above the atmosphere. Pump working perfectly.
1		Date of commencing the exp	10 A.M., April 2.	10 40 A.M., April 3.	9 A.M., April 1.
2	Total quantities.	Duration of the experiment i	24·	24·	24·
3		Number of cubic feet of wate	7,840·	9,760·	9,440·
4		Number of pounds of water steam siphon-pump, the the supply-tank, ...	505,752·	624,596·160	603,871·
5		Number of pounds of feed-v feeding the boiler and for	17,070·	16,710·	16,120·
6		Number of single strokes m lifting the above quantity	. . .	. . .	. . .
7		Number of single strokes ma the rotary-pump, lifting t	. .	. . .	. .
8	Steam cylinder.	Number of single strokes mac reciprocating and the rota	. . .	. . .	. . .
9		Number of single strokes ma tions made per minute by	. . .	. . .	. . .
10		Steam pressure in boiler, in po	20·	30·	40·
11		Throttle valve, ...	Wide open.	Wide open.	Wide open.
12		Barometer, in inches of mercu	30·11	30·38	29·79
13		Estimated mean total pressure	. . .	. . .	. . .
14		Estimated mean back pressure	. . .	. . .	. . .
15		Estimated mean gross-effectiv	. . .	. . .	. . .
16		Estimated pressure on the cylinder and its attached	. . .	. . .	. . .
17		Estimated net pressure on the	. . .	. . .	. . .
18		Estimated total horse power c	. . .	. . .	. . .
19		Estimated gross effective hors	. . .	. . .	. . .
20		Estimated net horse-power de	. . .	. . .	. . .
21	Temperatures.	Temperature of the external a	46·7	40·4	44·8
22		Temperature of the room in w	68·9	75·0	72·7
23		Temperature, in the supply-ta	60·0	68·0	71·0
24		Temperature, in the receiving	100·0	98·0	100·0
25	Duty.	Number of pounds of water r	29·628	37·378	37·461
26		Number of pounds of water r	523·430	660·355	661·811
27	Pumps.	Cubic inches of water dischar revolution of the rotary p	. . .	. . .	. . .
28		Space displacement, in cubic of the piston of the rotary	. . .	. . .	. . .
29		Fraction of the space displac per revolution of the pisto	. . .	. . .	. . .

Table containing the data and results of experiments, made in 1867 at the New York Navy Yard, to determine the relative economic efficiency, in proportion of weight of steam used to weight of water lifted, of a reciprocating-pump, a rotary-pump and a steam siphon-pump, all three raising water to the same elevation of 17 feet 8 inches.

Number of Line			Reciprocating-Pump.	Rotary-Pump.	Steam Siphon-Pump.		
			Steam cylinder, 9 inches diameter and 6 inches stroke of piston, using the steam without expansion and without condensation. Diameter of piston-rod, 1¾-inch. Net area of steam piston, 62·414 square inches. Water cylinder or pump, 5 inches diameter and 6 inches stroke of piston. Diameter of piston-rod, 1¼-inch. Net area of piston, 18·433 square inches. Receiving-pipe of pump, 2¾ inches inner diameter and 3 feet 7 inches long. Discharging-nozzle of pump, 2¾ inches diameter inside, to which is belted a discharging-pipe of 1½-inch inner diameter and 28 feet length.	Steam cylinder 9 inches diameter and 6 inches stroke of piston, using the steam without expansion and without condensation. Diameter of piston-rod, 1¾-inch. Net area of steam piston, 62·414 square inches. The water cavity of the pump is 7 inches in diameter and 5 inches in length. The pump has no valves, and it is geared up by pullies and belt, to make 2·3 revolutions to each double stroke of the steam cylinder-piston. Receiving-pipe of pump 2 inches inner diameter and 5 feet 5 inches length. Discharging-pipe, 1½-inch inner diameter and 22 feet length.	Two receiving-pipes, each 2 inches internal diameter and 40 inches long. One discharge-pipe, 2 inches internal diameter and 22 feet long. The centre of the pump or mouth of steam-jet is 54 inches above the surface of the water in the supply-tank. Steam-pipe, from boiler to pump, 1½-inch internal diameter, 20½ feet long, and felted.		
					Steam-jet nozzle, ¾-inch in least inner diameter, used with steam of 20 pounds per square inch pressure above the atmosphere, which was the least pressure with which the pump would work, and even then very imperfectly, stopping about once an hour, with heavy concussions, and requiring the pump chambers to be cooled before again starting.	Steam-jet nozzle ⅝-inch in least inner diameter, used with steam of 30 pounds per square inch pressure above the atmosphere. Pump working perfectly.	Steam-jet nozzle, 9-16-inch in least inner diameter, used with steam of 40 pounds per square inch pressure above the atmosphere. Pump working perfectly.
1		Date of commencing the experiment,	12.30 P.M., March 11.	12.39 P.M., March 4.	[illegible] A.M., April 2.	10 40 A.M., April 3.	9 A.M., April 1.
2	Total Quantities.	Duration of the experiment in consecutive hours,	72·	72·	24·	24·	24·
3		Number of cubic feet of water lifted from the supply-tank through a vertical height of 17 feet 8 inches,	52,240·	45,280·	7,840·	9,760·	9,440·
4		Number of pounds of water lifted through a vertical height of 17 feet 8 inches; including, for the steam siphon-pump, the pounds of water on line 5, in addition to the pounds of water raised from the supply-tank,	3,255,353·	2,822,388·	505,752·	624,596·160	603,871·
5		Number of pounds of feed-water pumped into the boiler and vaporized to supply the steam for feeding the boiler and for lifting the above quantity of water 17 feet 8 inches high,	23,993·	25,970·	17,070·	16,710·	16,120·
6		Number of single strokes made by the piston of the steam cylinder, which operated the pumps, lifting the above quantity of water 17 feet 8 inches high,	944,640·	1,086,261·	...	...	...
7		Number of single strokes made by the piston of the reciprocating-pump, and of revolutions made by the rotary-pump, lifting the above quantity of water 17 feet 8 inches high,	944,640·	1,249,200·	...	...	...
8	Steam Cylinder.	Number of single strokes made per minute by the piston of the steam cylinder, which operated the reciprocating and the rotary pumps,	218·667	251·450	...	...	...
9		Number of single strokes made per minute by the piston of the reciprocating-pump, and of revolutions made per minute by the rotary-pump,	218·667	289·167	...	...	...
10		Steam pressure in boiler, in pounds per square inch above the atmosphere,	30·	30·	20·	30·	40·
11		Throttle valve,	Partly closed.	Partly closed.	Wide open.	Wide open.	Wide open.
12		Barometer, in inches of mercury,	30·17	30·45	30·11	30·38	29·79
13		Estimated mean total pressure on the steam piston, in pounds per square inch above zero,	30·00	28·25	...	...	...
14		Estimated mean back pressure against the steam piston, in pounds per square inch above zero,	15·50	15·50	...	...	...
15		Estimated mean gross-effective pressure on the steam piston, in pounds per square inch,	14·50	12·75	...	...	...
16		Estimated pressure on the steam piston, in pounds per square inch, required to work the steam cylinder and its attached pump, *per se*: that is, without load,	1·50	1·50	...	...	...
17		Estimated net pressure on the steam piston, in pounds per square inch,	13·00	11·25	...	...	...
18		Estimated total horse power developed by the steam piston,	6·204	6·715	...	...	...
19		Estimated gross effective horse-power developed by the steam piston,	2·999	3·031	...	...	...
20		Estimated net horse-power developed by the steam piston,	2·688	2·674	...	...	...
21	Temperatures.	Temperature of the external atmosphere, in degrees Fahrenheit,	37·0	31·2	46·7	40·4	44·8
22		Temperature of the room in which the apparatus was situated,	66·7	64·2	68·9	75·0	72·7
23		Temperature, in the supply-tanks, of the water lifted 17 feet 8 inches high,	63·0	60·0	60·0	68·0	71·0
24		Temperature, in the receiving-tanks, of the water lifted 17 feet 8 inches high,	63·0	60·0	100·0	98·0	100·0
25	Duty.	Number of pounds of water raised 17 feet 8 inches high, by one pound weight of steam,	135·670	108·679	29·628	37·378	37·461
26		Number of pounds of water raised one foot high by one pound weight of steam,	2,397·001	1,919·992	523·430	660·355	661·811
27	Pumps.	Cubic inches of water discharged per single stroke of the piston of the reciprocating-pump, and per revolution of the rotary pump,	95·561	62·635	...	...	...
28		Space displacement, in cubic inches, of the piston of the reciprocating-pump per single stroke, and of the piston of the rotary-pump per revolution,	110·580	109·000	...	...	...
29		Fraction of the space displacement per single stroke of the piston of the reciprocating-pump, and per revolution of the piston of the rotary-pump, filled with water,	0·864	0·575	...	...	...

power (line 20) in the two cases will be considered as expressing correctly the relative cost of the pumping. Measured by this standard, the duty of the reciprocating-pump compared with that of the rotary-pump as

$$\frac{3255353}{2{\cdot}688} \text{ to } \frac{2822388}{2{\cdot}674},$$

or the former was 1·147 times greater than that of the latter.

As the belt communicating the motion of the engine to the rotary-pump caused certainly some friction and had probably some slip, an allowance must be made for these causes of inferiority, because they are not necessary to the pump, which could be worked directly by the engine. When the results of these abnormal causes are eliminated, and when the resistance of the valves of the reciprocating-pump is taken into comparison—the rotary-pump having no valves—the economic performance of the rotary-pump will be found but little less than that of the reciprocating-pump.

The permanent cause of inferiority in the rotary-pump will be found chiefly in the greater water leakage past its pistons, and this leakage is of a nature to increase to a higher proportion as the head of water increases against which it works. Neither can this pump, with its uniformly revolving pistons, fill with water the same proportion of the space displacement of its pistons that the reciprocating-pump can, with its piston coming to a state of rest at the end of its stroke. Hence, we find by inspection of line 29 of the table that, while water to the quantity of 0·864 of the space displacement of its piston was discharged by the reciprocating-pump, the rotary-pump discharged water to the quantity of only 0·575 of the space displacement of its piston.

HARBOR BAR IMPROVEMENTS.

DISCUSSION BY PROF. L. M. HAUPT.

Since, to ignore the criticisms of Prof. L. d'Auria, as published under this caption in the last number of the JOURNAL, would leave the readers under serious misapprehensions, it would seem to be necessary to submit a few comments in reply.

In the opening paragraph * it is stated in substance that I believe our Government disregards the importance of removing bars from harbor entrances, because it has not as yet seen fit to adopt the plans which I have respectfully submitted looking to that end.

How widely this remarkable assertion differs from the facts will be seen by even a casual reading of my original paper † wherein I have attempted to show that, instead of disregarding the importance of this measure, the United States has endeavored, by all possible means, to effect some substantial improvements, even to the extent of spending large amounts of money and many years in work; but, as I claim, without substantial results. In view of such a finding it became a duty on my part, if possible, to discover the cause and suggest a remedy, and this I have essayed to do. If the Government has not yet seen fit to test these plans it does not follow that others may not, and the writer must have been ignorant of the fact that a foreign government is seriously considering the advisability of their introduction, or he would not have asked the question contained in the second paragraph.

With reference to the measurement of the forces, I have definitely stated that I prefer the measurement as revealed by nature, in the resulting effects produced by their action, rather than theoretical computations based upon a limited number of instrumental observations as to the force and

* Page 224.

† Page 23 and particularly on p. 31.

direction of winds, waves, tides and currents. For, however accurate these latter may be, who can combine them into a formula which shall express the resultant of all of these ever-varying physical conditions? In the computation made in the paper under consideration, the author attempts to discredit my statement that the proposed jetties at Galveston will interfere with the free ingress of the flood, by deducing a formula for the mean velocity of any section, but unfortunately it is not applicable, since it does not include the frictional resistance due to a channel five miles long. It is not to be supposed that for a given difference of level, the surface slope, and hence the velocity, will be the same for a channel five miles long as for one (say) five feet long. Moreover, the Board of Engineers, in their report on the plans for the Galveston jetties, admit that these structures do obstruct the ingress of the flood, for they say, "Such a jettied channel offers more resistance to inflow than does the present entrance; reduces the tidal prism about one-third and hence gives greater difference of level," etc., and again in concluding their report, "The jetties will diminish the freedom of inflow at Galveston." * In short, the attempt to disprove my statement by a formula, merely confirms the conclusion reached by the late talented engineer, General Gillmore, who, after years of experience, said, in speaking of the action of these forces of nature, "The question is full of perplexing difficulties, which elude all the known methods of research by formulæ." †

Again, concerning the demonstration introduced to prove that the "*tidal-wave*" has not sufficient velocity to produce the changes I have mentioned, I have merely to add that there seems to be a further continued misunderstanding of my language, for I have repeatedly disclaimed asserting that it is the tidal *wave*, but on the contrary have given the term *flood component* to the combined forces, causing the observed effects, and have defined this to "include the dynamic action of the breakers racing along the shore as

---

* *Vide*, pp. 24, 25, vol. cxxxiii, this JOURNAL.

† *Report Chief of Engineers*, 1876, p. 458.

well as the littoral currents generated by the on-shore movements of the flood tide." *

The direction of this flood component or resultant I have attributed to the angle at which the flood-tide approaches the foreshore. By the "racing of the tidal crests," which appears to be the stumbling-block, is meant simply the incessant rolling up of the breakers, generally in an oblique direction, determined largely, as I maintain, by the flood currents, and not the movement of the crest of the tidal-wave, which only occurs at comparatively long intervals.

Finally, Professor d'Auria appears to think the American Philosophical Society were not justified † in awarding the Magellanic Premium for the paper on the "Physical Phenomena of Harbor Entrances," ‡ although it was in its possession for about *nine months* for consideration, and the authorship was *unknown*. The recommendation of the award was made in the earliest possible months permitted by the regulations and it was approved at the same meeting; but this is a part of the subject which I do not feel at liberty to discuss further, since I do not question the competency of the committee, and have abundant reasons, from subsequent examinations and correspondence relative to shore movements, to believe my statements concerning the changes constantly recurring along our alluvial coasts to be fully confirmed by experience, and the Society correct in its conclusions.

As to the congratulations extended to the State of Texas for deliverance from my plans, it may be said that some of the ablest of her civil engineers, as well as prominent citizens living at the very ports under consideration, for periods reaching fifty years, have strongly commended these plans as being the best they have seen and the most likely, in their opinion, to furnish the desired relief.

These personal allusions are believed to be necessary in consequence of the peculiar character of the objections

---

* *Proceedings of the American Philosophical Society*, March, 1889.

† *Vide* p. 227, this JOURNAL, for September.

‡ *Vide Proceedings American Philosophical Society*, 1888.

urged in the paper published in the September number of the JOURNAL.

Opinions are not facts and presumptions are not arguments.

MECHANICAL PROGRESS—THE PAST AND PRESENT CONTRASTED.*

BY GEORGE B. PRICE, M.E., Member of the INSTITUTE.

The purpose of this paper is to indicate something of the wonderful growth of our manufacturing industries in the last twenty years, and to call attention to the wide difference in systems, marking this from previous epochs; especially the introduction of the drafting room, as one of, if not the chief factor in promoting this unparalleled growth of mechanic arts.

To show the invariable superiority of one method over all others for accomplishing a purpose, and to be able to prove by many notable examples the unquestionable value of such method, is to show, at once, the road by which the live men of to-day are winning a deserved success, and a very possible cause of partial failure to those who are yet unacquainted with the very radical change in the situation.

Nothing is truer to this century than the oft-heard phrase, "the world moves on."

Time was when men were satisfied with candle-light.

The ship in which Columbus sailed was doubtless looked upon as a noble craft. Men, for centuries, plowed the earth with wooden plowshares, and the smith at his forge was the nobleman in mechanical skill.

Our century, with its myriad wheels of invention, looks back upon those times as upon a world in its infancy. It was in its infancy. Then men toiled as best they knew how; and with commendable zeal constructed the argosies that have floated humanity to the portals of a new age.

From those portals a new light is shining, with promise of untold wealth. The rapid accretion of knowledge in the scientific world has evolved principles that men knew

* Read by title at the Stated Meeting held Wednesday, September 18, 1889.

nothing of, even a century ago; but which, being recognized and practically applied, are stimulating the great world of industries, abrogating the old and instituting revised methods, to such an extent that men have now grown perfectly familiar with the quotation that "things are not now done as they used to be." How very true! Instead of a small wooden hull, drifting uncertainly upon an almost impassable sea, we have now the advantage of swift and massive "ocean greyhounds," whose grace and perfection tell of a new world of mechanic arts. The smith at his forge, toiling with scarce-requited labor, to express in rude form the conceptions of his individual brain, has given place to our splendid machine shops and great foundries, equipped with "plant" that now makes easily possible what once had been more than a Utopian dream.

The secret of all this change, this wonderful accretion of the wealth of the world, is the genius of invention, controlled by scientific knowledge and wrought out by the subdivision of labor.

This means, when practically applied to our present subject: First, the conception, in one or more minds, of the elementary ideas of an invention. To embody this invention is the work, next, of the mechanical engineer, whose province it is to consider the various principles of construction that enter into the combination; to adjust the different parts to each other and to the whole, having regard to the required solidity, stability, flexibility, simplicity and economy, as well as the most approved or possible methods of casting, welding, finishing and joining those parts, considerations which may not only affect the ultimate practicability of the invention, but, according to the manner in which the subject is treated, will depend largely the grace, symmetry and perfection of the machine.

The position of the mechanical engineer, in this early stage of the work, is as unique as it is important. He is like the doctor who is versed in the principles of medicine, but who, according to his appreciation of the conditions of the case, not less than the ingenuity of his resources, may often build up the patient speedily and lastingly, or only partially and imperfectly.

The physician of known ability is quite likely to be the cheapest in the end; so the timely employment of the engineer is almost certain to mean the best construction of the work proposed, in the shortest time and with the most economy in ultimate cost.

From the hands of the engineer (who should follow up and superintend the subsequent construction) the plans and specifications go into those of the several workmen who are individually instructed, by the drawings, as to the proper way of working up their respective details. There is in this way no clashing or confusion, each man being responsible only for the correct production of his part.

Such seems to be the true explanation of the economic principles of the subdivision of labor.

Men have found out *principles*, and that the most progress is made and wealth more rapidly accumulated when the several stages of any piece of work are each guided and controlled by those who have made *that part* their special study.

We have a very limited idea of the subdivision of labor when we think of it only as of a number of men being divided into groups for the several manual operations in forming, say, a pin. This, indeed, is subdivision of labor; but it should mean more than this. It presupposes antecedent skill and varied ability of a high order.

Before the finished product was possible, an intricate piece of machinery had to be built; which further presupposes not only skilled mechanics, but an inventive genius, and an ability, of somebody, to understand the requirements and correctly portray on paper the many parts, in detail, and as a whole. The designer was quite as necessary as the inventor or the workman.

Let it be remembered, then, that the workshop, though necessary for the practical embodiment of the invention, is yet distinct from the invention. The rule of true progress here is plain. The invention must first be clearly conceived and plainly drawn on paper, clearly and in detail, carefully and studiously designed according to the principles governing the particular construction; in short, it should be wholly

created and visibly expressed in every detail, by one who is master of the subject, before it is put into the hands of a single workman.

How many ambitious, bright, but over-sanguine men have conceived a general notion of some invention, involving mechanical principles of which, most likely, they knew little or nothing, and have thrown away time and hundreds—perhaps thousands—of dollars in blundering along—time and money that might have been saved had they started aright. Most assuredly it can be said, with emphasis, no matter how great or how small the new work proposed, construct it first on paper!

Progressive manufacturers and machinists everywhere are every year recognizing more forcibly the value of this method, and, recognizing it, are growing richer. Look into our best workshops of to-day; the great foundries and machine works that turn out our exact machinery, our fine locomotives, our floating palaces; in all you will find—not "a rule of thumb" and endless experiment, but a well-constituted, thoroughly superintended drawing room. Here the work is first really constructed, on paper, the varied problems carefully thought out, the many parts fitted and proportioned to their several functions; then the various artisans and workers are given their parts, and the whole structure grows uniformly, rapidly, to perfect completion. This is the new way. It has come to stay.

It might be interesting to some to have described the actual working routine of one of our largest and most successful manufacturing establishments—the great locomotive works, whose world-wide reputation has made the American locomotive famous as a competitor on almost every line of railroad in the civilized world. One might naturally conclude that the system preferred by such a firm, after years of fruitful experience—the system which turns out two completed locomotives a day—ought to have superior merit; and if any doubt of this should remain in any one's mind, it should be fully dispersed by the further announcement that the virtues of that same system are being appreciated, and as far as possible imitated by com-

petitive concerns, whose capacity and business are being rapidly enlarged in consequence.

Let us, then, take a swift glance through the said establishment, beginning with the drafting room, which is properly the starting place for our inspection. Here, in a well-lighted, ample apartment, are a number of draftsmen, many of them brought up in the service. These are under the supervision and direction of a superintendent, who originally decides upon the plan of each locomotive to be built, estimating its capabilities and requirements. Instructions and a specification are then given to a draftsman in charge, who carefully constructs on paper elevations and sections necessary to the complete locomotive. The detail drawings are then executed on stiff card-boards, or other materials suited to stand shop-wear, and after passing satisfactory inspection of the examiner of drawings, are given out, carefully numbered and registered, to the respective shops. No work can be done in any of the shops until this is done, thus manifesting the high importance which this successful establishment attaches to correct drawings as the starting point for all construction.

In the shops, the many details are each carefully wrought out, in strict conformity to the drawing, and, as completed, sent to the erecting shop, where, under competent foremen, the various parts are rapidly adjusted, each falling into its proper place, and in an incredibly short time the completed locomotive is breathed into by the breath of its steam-life, and starts upon its career, a giant of force and a monument of engineering skill.

Time was when a complete preliminary drawing was hardly known in a machine shop. Then, men blundered, and blunders are always costly. Time will be soon, when a machine shop without its drawing room, its superintending engineer, will be but a lingering reminder of an experimental age before men had learned the true source of progress and wealth.

Those that still cling, like the smith of old, to the methods of a by-gone age, are falling behind in the race, for while, in a sense, they may be laboriously building up a

small trade, others, taking advantage of the proven better methods for success, will be forging ahead into enviable wealth.

The former has been left behind, not because of inferior ability, in his line, but because he has lost time in trying himself to do what another could have better done, at less expense to him.

There is another and concluding thought that should give hope to every man in the mechanic world.

As his craft grows into closer relationship with the great world of science about and above him, it will certainly lift him to a higher plane. Men are everywhere realizing, as never before, the everlasting truth of fixed principles and universal law governing all things. If a house falls, a bridge gives way, a dam bursts its confines, it is no longer an unaccountable event. Something was deficient. The capacity to detect the cause, the power to avert the evil by a scientific knowledge of the principles of construction is, of all knowledge, the most useful, while its possession, in proportion to its completeness, should raise its possessor to the first ranks among men.

CHAS. A. TEAL'S PORTABLE HOIST.

[*Report of the Committee on Science and the Arts.*]

[No. 1402.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April, 1889.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred the application of the Teal Hoist Company of Philadelphia, for an examination and report upon the merits of

AN IMPROVED CHAIN HOIST PATENTED BY CHAS. A. TEAL, OF PHILADELPHIA, APRIL 8, 1884, NO. 296,364,

Report that: As will be seen by a copy of the patent annexed and by examination of the hoist exhibited:

The hoist consists of a malleable-iron frame suspended

by means of a swivel and hook, much in the usual form of such hoists, but supporting a novel and ingenious form of differential mechanism.

There are several well-known differential hoists in the market, but they all differ widely from Teal's invention.

The nearest approach to it would appear to be the "Weston Chain Hoist," which has two sprocket-wheels cast together or connected side by side upon a shaft, upon which they can turn freely; one of the wheels is larger than the other, having usually one tooth more.

The lift-chain is endless and is so arranged upon these sprocket-wheels that, as they are revolved, the chain runs like a belt, up on one side and down on the other.

The difference between these wheels causes a lengthening or shortening of a bight of the chain, in which the hoisting hook is carried, as the wheels are turned back or forward by a pull upon the lift-chain, and thus any weight attached to the hook is raised or lowered.

In the Teal Hoist the two sprocket-wheels are not side by side, but are upon separate shafts, and they are of the same size; they are also upon opposite sides of a pinion, mounted centrally in the frame of the hoist.

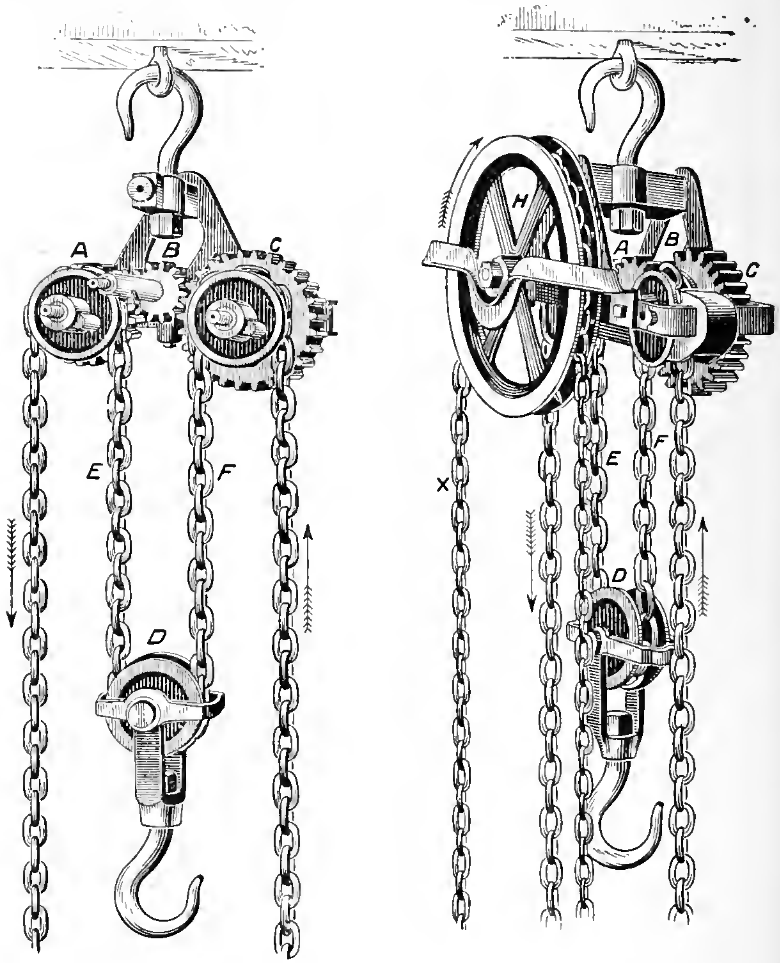
Each sprocket-wheel is connected to this pinion by a spur gear, cast upon the side of the sprocket-wheel, so that the pinion as it revolves turns the sprocket-wheels also.

The sprocket-wheels, while they are of the same size, do not revolve at the same velocity, because one of the gears is larger than the other, and will require more time in which to complete its revolution.

The lift-chain is carried upon these wheels, much in the same way as in the "Weston Hoist," being carried up by one wheel and down by the other, at different velocities, however, for the two motions, and a bight of the chain in which the hoisting hook is carried is made longer or shorter as the central pinion is turned backward or forward.

This pinion has a large grooved wheel upon the outer end of its shaft, and a small endless hand-chain is carried in the groove, so that the wheel and pinion are revolved back or forward by a pull upon the hand-chain. Thus any

load attached to the hoisting hook will be lifted by a pull upon the hand-chain and at a velocity and with an expenditure of force proportioned to the velocity ratio between



the hoisting hook and hand-chain, allowance being made also for the friction of the machine.

This arrangement of the sprocket-wheels, gears and lift chain has also another peculiar action, with consequent advantage.

In the "Weston Hoist" the hoisting hook is lowered by

pulling upon one side of the lift-chain, and raised by pulling upon the other; the only difference being that when the hook is empty the lowering motion may be somewhat quickened, because the chain runs freely and a rapid motion can be given to the chain.

So also in all other hoists known to us, the overhauling or lowering of the hook, is a mere reversing of the hoisting action, and requires the same time as to lift a load; there being in them no provision for applying power to any other part of the hoist, than that by means of the hand-chain, by which the lifting is done.

The Teal hoist, on the contrary, has a slow and powerful motion to lift its load, by means of the hand-chain; and a quick movement for overhauling the chain and lowering the hook for a second lift by a pull directly upon the lift-chain. (This will be seen by examining the machine.)

Supposing the convenient velocity in pulling the two chains to be the same; then in the 1,000-pound hoist examined by us, the hook can be overhauled five times faster by a pull upon one side of the lift-chain, or six seven-tenths times faster by pulling on the other side, than it can be by the hand-chain. This increases the capacity and usefulness of the hoist and is therefore a valuable improvement.

The extent of this improvement can be seen more fully, perhaps, in the table annexed, which gives the velocity ratio and overhauling speed of several well-known hoists, with the ratio of increase in the Teal hoist:

	Capacity.	Hand-Chain to Hook Velocity Ratio.	Overhaul.	Increase Speed.
	Pounds.	*Inches.*	*Inches.*	
Weston,	1,000	23 to 1	23 to 1	None
Harrington,	1,000	60 to 1	60 to 1	"
Box,	1,000	36 to 1	36 to 1	"
Wharton,	1,000	36 to 1	36 to 1	"
Teal,	1,000	38·5 to 1	7·62 to 1	5 times.
Teal,	. . .	. . .	5·74 to 1	6 7-10 times.

The use of gears to produce the differential action in place of sprocket-wheels having a different number of teeth, permits the use of a much higher velocity ratio, because the difference between the two sprocket-wheels cannot be

less than one tooth of the wheels or one link in the chain; this would require a very large sprocket-wheel and would be quite impracticable, because of the great increase of weight in the hoist, if the velocity ratio was equal to that readily obtained with gears having small diameter combined with small sprocket-wheels, and therefore having much less weight, as shown in Teal's invention.

This increase of power would, however, soon reach a point where the very slow overhauling speed resulting would more than counterbalance the advantage gained, but for the increased speed due to the pull upon the lift-chain.

The general arrangement and workmanship of the hoist are good. The journals are made self-oiling by having a chamber filled with fibrous packing combined with each journal, and while we think some parts of the malleable iron framing could be with advantage increased in weight and strength, we regard it as upon the whole an excellent hoist, with such novelty and advantage as fully entitle it to receive an award from the committee.

Copy of Report of Tests of Portable Chain Hoists, made at the "Novelties" Exhibition, Franklin Institute, October 20, 1885; also, Report of Tests of Teal's Hoist under same Headings.

Make.	Capacity.	Shortest Distance Between Hooks.	Movement of Hand-Chain to Movement of Hook.	Weight Lifted.	Weight Required To— Start Load.	Weight Required To— Keep Load Moving.	Per Cent. of Power Wasted in Friction.
	Pounds.	*Inches.*		*Pounds.*	*Pounds.*	*Pounds.*	
Harrington,	2,000	18	60	1005½	44	41	59·02
Olsen,	2,000	21	47¼	1005½	66	54	60·6
Wharton,	2,000	20	52½	1005½	79½	68½	72·05
Box,	2,000	18½	42½	1005½	87	73	67·78
Reid,	500	18¾	38½	282	35½	20	63·40
Teal,	1,000		38½	350	21·7	20	54·6
					Average 20 tests.	Average.	Main chain did not run freely as it should.

The results of the tests made by your committee are given above, and in such a manner as to enable a comparison

to be easily made with those obtained by the committee appointed by the Judges of Group No. 13*b*, at the "Novelties" Exhibition of 1885, on Portable Hand Hoists.

In view, then, of the very high efficiency of the hoist, as compared with those tested previously, this hoist showing a considerable increase over the best one then tested, and in view of the increase of capacity and speed in overhauling, we would recommend the award of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to Chas. A. Teal for his invention.

[Signed] MOSES G. WILDER,
Chairman Sub-Committee.
FRANCIS LECLERE.

Adopted, May 1, 1889.

[Signed] S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

LECTURES FOR THE SEASON 1889-'90.

The following is the programme of the Lectures to be held during the ensuing winter:

1889.

Monday, November 4.—Daniel Ammen, Rear Admiral, U. S. N., Washington, D. C. *Subject*, "Proposed American Isthmian Canal Routes."

Friday, November 8.—Prof. Lewis M. Haupt, University of Pennsylvania. *Subject*, "Municipal Engineering."

Monday, November 11.—Prof. Ira Remsen, Johns Hopkins University, Baltimore, Md. *Subject*, "Stereo-Chemistry."

Friday, November 15.—Prof. W. LeConte Stevens, Packer Collegiate Institute, Brooklyn, N. Y. *Subject*, "The Development of Aëronautics." (Illustrated.)

Monday, November 18.—Dr. H. Hensoldt, Columbia College, School of Mines, New York. *Subject*, "Natural History in Elementary Schools."

Friday, November 22.—Mr. Chas. Heber Clark, Editor *Textile Record*, Philadelphia. *Subject*, "Work, Waste and Wages."

Monday, November 25.—Prof. C. Herschel Koyl, Washington, D. C. *Subject*, "The Evolution of Railroad Signalling."

Friday, November 29.—Mr. C. John Hexamer, Philadelphia. *Subject*, "A Descriptive and Illustrated Sketch of Canada."

Monday, December 2.—Prof. C. Hanford Henderson, Manual Training School, Philadelphia. *Subject*, "A Lay Sermon on Chemistry."

Friday, December 6.—Mr. Fred. E. Ives, Philadelphia. *Subject*, "The Optical Lantern as a Means of Demonstration." (Illustrated.)

Monday, December 9.—Mr. T. Dunkin Paret, President of the Tanite Company, Stroudsburg, Pa. *Subject*, "Emery Wheels."

Friday, December 13—Mr. Wm. M. Barr, Philadelphia. *Subject*, "The Duty of Pumping Engines."

Monday, December 16.—Mr. Ralph W. Pope, New York, Secretary American Institute of Electrical Engineers. *Subject*, "Electricity: its Past, Present and Future."

Friday, December 20.—Mr. Thomas Pray, M.E., C.E., Boston, Mass. *Subject*, "What Does a Steam Horse-Power Cost?"

1890.

Monday, January 6.—Prof. F. W. Clarke, U. S. Geological Survey, Washington, D. C. *Subject*, "Coal Products."

1890.

Friday, January 10.—Mr. John Carbutt, Philadelphia. *Subject*, "Some New Applications of Photography." (Illustrated.)

Monday, January 13.—Prof. R. L. Chase, Pennsylvania Museum and School of Industrial Art." *Subject*, "A Revolution in Dyeing."

Friday, January 17.—Prof. W. LeConte Stevens. *Subject*, "The Mammoth Cave of Kentucky." (Illustrated.)

Monday, January 20.—Lieut. Bradley A. Fiske, U. S. N. *Subject*, "Electricity in Warfare."

Friday, January 24.—Dr. Edward D. Cope, Philadelphia. *Subject*, "The Influence of Inherited Characters."

Monday, January 27.—Dr. W. Thomson, Philadelphia, Professor Ophthalmia and Surgical Expert Pennsylvania Railroad Company. *Subject*, "Color Blindness."

Friday, January 31.—Mr. C. John Hexamer. *Subject*, "A Descriptive and Illustrated Sketch of Germany."

Friday, February 3—Prof. Louis Duncan, Johns Hopkins University, Baltimore. *Subject*, "Modern Conceptions of Electricity."

Friday, February 7.—Mr. Theodore C. Search, Philadelphia. *Subject*, "Wool—from the Fleece to the Card."

Monday, February 10.—Mr. Eugene Griffin, Thomson-Houston Electric Company, Boston. *Subject*, "Electric Railways."

Friday, February 14.—Mr. Theodore C. Search. *Subject*, "Wool—from the Card to the Fabric."

Monday, February 17.—Mr. Geo. F. Kunz, New York. *Subject*, "Precious Stones." (Introducing copious Lantern Illustrations of the Paris Exposition.)

Friday, February 21.—Mr. Wm. F. Durfee, Superintendent Pennsylvania Diamond Drill Company, Birdsboro, Pa. *Subject*, "Diamond Drilling."

Monday, February 24.—Dr. Charles B. Dudley, Chemist to the Pennsylvania Railroad Company, Altoona, Pa. *Subject*, "Bearing-Metal Alloys."

Friday, February 28.—Mr. Fred. E. Ives. *Subject*, "Street Scenes in Italy caught with the Camera."

Arrangements are being made for a series of illustrated practical lectures on various handicrafts, designed especially for the instruction of apprentices. Due announcement will be made of this portion of the programme when completed.

By direction of the Committee on Instruction.

Wm. H. Wahl, *Chairman.*

Approved by the Board of Managers, Wednesday, Sept. 11, 1889.

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, September 17, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 17, 1889.

Mr. H. PEMBERTON, Jr., President, in the Chair.

Members present: W. H. Bower, Reuben Haines, H. W. Jayne, L. J. Matos, W. W. McFarlane, Thos. N. Newbold, H. Pemberton, Jr., Dr. Wm. H. Wahl, W. D. Weikel.

The resignation of Marshall R. Pugh, to take effect at the end of current year, was presented and accepted. The President read a copy of a proposed amendment to the By-Laws of the INSTITUTE relating to Sections, under which the Sections would be empowered to admit to associate and corresponding membership others than members of the INSTITUTE.

The President exhibited several specimens of the aqueous solution of the allotropic silver, described by Mr. M. Carey Lea.

Dr. Wahl presented for inspection a specimen of aluminium, manufactured at present on the commercial scale by the Pittsburgh Reduction Company. The process employed is that of —— Hall, of Oberlin, O., which consists substantially in dissolving alumina by igneous fusion in a bath of metallic fluorides, and electrolyzing the resulting solution, by which, it is affirmed, the alumina is decomposed while the solvent remains unaffected. Dr. Wahl spoke in general terms of certain technical applications of aluminium, especially to the increasing use of ferro-aluminium by foundrymen to improve inferior irons. He also exhibited several medallions struck from aluminium, made by the Aluminium Company, limited, at the works at Oldbury, near Birmingham, England. They had been presented by Mr. H. Y. Castner, whose process is there in operation.

Adjourned. H. W. JAYNE, *Secretary pro tem.*

Following is a list of the members of the CHEMICAL SECTION at the present time:

Allen, A. W.,	Pencoyd Iron Works, Pencoyd, Pa.
Bower, Henry,	Twenty-eighth and Gray's Ferry Road.

Bower, W. H.,	Twenty-eighth and Gray's Ferry Road.
Browning, G. G.	44 N. Front St.
Bullock, Charles,	528 Arch St.
Bullock, Wm. W.,	528 Arch St.
Campbell, J. H.,	Kingman, Mojave Co., Ariz.
Carter, John E.,	Coulter and Knox Sts., Germantown.
Chase, Prof. R. L.,	1336 Spring Garden St.
Clarkson, Philip S.,	Quaker City Dye Works, 110 Oxford St.
Cresson, Dr. Chas. M.,	413 Locust St.
Day, Prof. W. C.,	Swarthmore College.
DeBalas, Victor,	44 N. Front St.
Eastwick, J. H.,	Wissahickon Station.
Eastwick, A. T.,	Wissahickon Station.
Fisher, R. A.,	2239 St. Alban's Place.
Frankel, Lee K.,	University of Pennsylvania.
Frazer, Dr. Persifor,	Drexel Building, Room 1042.
Garrison, F. Lynwood,	Radnor, Pa.
Greene, Dr. Wm. H.,	204 N. Thirty-sixth St.
Haines, Reuben,	738 Sansom St.
Hall, Prof. L. B.,	Haverford College.
Hooker, Dr. S. C.,	Franklin Sugar Refinery.
Hunter, Thos. G.,	Fifty-fifth St. and Paschall Ave.
Ives, Fred. E.,	Crosscup & West, Ninth and Filbert Sts.
Jayne, E. C.,	242 Chestnut St.
Jayne, H. W.,	931 N. Broad St.
Keiser, Dr. E. H.,	Bryn Mawr College.
Keller, Dr. H. H.,	University of Pennsylvania.
Koenig, Dr. Geo. A.,	University of Pennsylvania.
Lea, M. Carey,	430 Walnut St.
Lewin, F. C.,	1011 Spruce St.
Lewis, John T.,	242 S. Thirteenth St.
Lichenheim, Jacob,	1614 N. Tenth St.
Lüthy, Dr. Otto,	2336 Fairmount Ave.
McFarlane, W. W.,	1600 Park Ave.
Matos, L. J.,	3943 Fairmount Ave.
Morris, Dr. L. I.,	2505 Oxford St.
Morton, Prof. Henry,	Stevens Institute of Technology, Hoboken, N. J.
Mucklé, Dr. Alex.,	1323 N. Nineteenth St.
Newbold, Thos. N.,	608 S. Forty-second St.
Newhall, Geo. M.,	136 S. Fourth St.
Oatley, Dr. E. L.,	4003 Chestnut St.
Palmer, T. C.,	22 N. Front St.
Pemberton, H.,	1947 Locust St.
Pemberton, H., Jr.,	1947 Locust St.
Petraeus, C. V.,	231 S. Front St.
Phillips, Geo. B.,	622 Race St.

Rand, Theo. D.,	17 S. Third St.
Rittenhouse, H. N.,	218 N. Twenty-second St.
Rowland, W. L.,	4800 Chester Ave.
Sadtler, Prof. S. P.,	204 N. Thirty-fourth St.
Schaffer, Dr. Chas.,	1309 Arch St.
Semper, C. J.,	505 S. Forty-first St.
Shaw, H. G.,	Thirty-second and Gray's Ferry Road, care Kalion Chemical Co.
Smith, Prof. Edgar F.,	University of Pennsylvania.
Thomas, Prof. N. Wiley,	Girard College.
Trimble, Prof. H.,	632 Marshall St.
Tuttle, Dr. N. K.,	U. S. Mint.
Wahl, Dr. Wm. H.,	Franklin Institute.
Warden, Henry,	307 Walnut St., 18th St. and Allegheny Ave.
Webster, Geo. C.,	Media, Pa.
Weikel, W. D.,	Merchantville, Camden Co., N. J.
Whitney, Asa W.,	1815 Vine St.
Wiegand, S. Lloyd,	146 S. Sixth St.
Wolf, Dr. T. R.,	Newark, Del.
Wolff, Lawrence, M.D.,	333 S. Twelfth St.
Wyeth, F. H.,	1412 Walnut St.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Agricultural Experiment Station of the Agricultural and Mechanical College, Alabama. Bulletin No. 6. New Series. From the Station.

American Association for the Advancement of Science. Proceedings of Thirty-seventh Meeting. From the Association.

American Gas Light Association Proceedings. Vol. 8. General Index to Proceedings. Vols. 1 to 8. From the Secretary.

American Institute of Mining Engineers. Eleven Pamphlets, Subject to Revision. From the Institute.

American Society of Civil Engineers. The New Notation of Time. From the Society.

Arkansas Geological Survey. Annual Report. 1888. Vols. 2 and 3. From the Secretary of State.

Art Union, Philadelphia. Fifth Report of the Board of Managers. From the Secretary.

Baker, L. W. The Alcohol Habit.
How Shall we Deal with the Inebriate.
Infectious Diseases. From the Author.

Bombay Magnetical and Meteorological Observations made at the Government Observatory. 1887. From the Government.

Brown, Harold P. Death from Electrical Currents.
Electrical Distribution. From the Author.

Bundy Radiator. Price List for 1889.
From the A. A. Griffing Iron Company.

Cheritree, Olive E. Evolution. From the Author.

Citizens' Association, Chicago. The Lakes and Gulf Water-way.
From Dr. O. Guthrie.

Clark Electric Company. Descriptive Catalogue.
From the Company.

Clarke, J. M. Report on Bones of Mastodon or Elephas.
From the Author.

Clauss Shear Company. Revised Price List. From the Company.

College of Science, Imperial University, Tokyo, Japan. Journal. Vol. 3. Part 1 and 2. From the College.

DeBausset, A. Looking Forward. From the Author.

DePauw University. Firty-first Year Book. From the Librarian.

Dyer, George L. Geography of the Sea. From the Author.

Engine, Boiler and Employers' Liability Insurance Company. Chief Engineer's Report for 1888. From the Chief Engineer.

Exposition Universelle Internationale de 1889. Congrés Internationale des Electriciens. From Carl Hering.

Floods of Pennsylvania. From Lorin Blodget.

French & Co. Illustrated Catalogue. From Benj. French & Co.

Genth, F. A. Contributions to Mineralogy. No. 44. On Two Minerals from Delaware County. From the Author.

Germanischer Lloyd. Internationales Register. 1889. Sechster Nachtrag.
From L. Westergaard & Co.

Goeppelsroeder, Friedrich. Ueber Capillar Analyse, mit Beilagen.
Farbelectrochemische Mittheilungen.
From the Author.

Guthrie, O. Memoirs of Dr. Samuel Guthrie.
The Great Lakes. From the Author.

Hale, Edwin M. The Cat and its Diseases. From the Author.

Harvard College. Annals of the Astronomical Observatory. Vol. 19. Part 1. Vol. 20. Part 2. From the Director of the Observatory.

Hebrew Technical Institute. Annual Report, 1889.
From the Director of Instruction.

Hichborn, Philip. Report on European Dockyards,
From the Navy Department.

Houghton, Mifflin & Company. Portrait Catalogue.
From the Company,

Inspector of Factories and Workshops of New Jersey. Sixth Annual Report for 1888. From the Chief Inspector.

Institution of Civil Engineers. Minutes of proceedings. Vol. 97.
Charter, Supplemental Charter, By-Laws, and List of Members.
From the Institution.

Internal Affairs of Pennsylvania. Annual Report of the Secretary for 1888. Part 3. From the Secretary.

Kansas Crop and Weather Bulletin. July, 1889. From the State Board of Agriculture.

Keystone, The. January to September, 1889. From C. N. Thorpe.

Königliche Technische Hochschule zu Hannover. Programm für das Studienjahr, 1889-90.

Little Falls, N. Y. Construction and First Annual Report of the Board of Water Commissioners. Rules and Regulations and Schedule of Water Rates. From Stephen E. Babcock, Chief Engineer.

Maritime Canal Company of Nicaragua.
Canal de Nicaragua.
The Nicaragua Canal. From the Company.

Massachusetts. Bureau of Statistics of Labor. 19th Annual Report. From the Chief of the Bureau.

Massachusetts Census, 1885. Vol. 1, part 2, and vol. 2. From the Secretary of State.

Massachusetts State Agricultural Experiment Station. Analysis of Commercial Fertilizers. August, 1889. From the Station.

Melrose, Mass. Report of the Board of Water Commissioners for 1887 and 1888. From the Board.

Meteorological Office, London. Official Publications, 81 and 82. From the Office.

Michaelis, O. E. Lime Sulphite Fibre Manufacture in the United States. From the Author.

Mills, T. Wesley. Physiological and Pathological Reversion.
Squirrels; their Habits and Intelligence. From the Author.

Missouri School of Mines. Catalogue, 1888-89. Description of Laboratory. From the Director.

Morison, George S. Report on the New Omaha Bridge. From the Author.

Müller, Frantisek. Kompendium Geodésie. 1 Dil. Cást Druhá. From Spolku Architektu a Inzenyrn.

Mullett Brothers. Catalogue and Price List. No. 10. From Mullett Brothers.

Musée Teyler. Archives. Série 2. Tome 3. 3[e] partie. From the Conservator.

New Jersey Agricultural Experiment Station. Bulletin F., 56, 57 and 58. From the Director.

New Mausoleum. A secure Sanitary Sepulchre. From the New Mausoleum Company.

New York, State of. Report of the Commission to Investigate and Report the most Humane and Practical Method of Carrying into Effect the Sentence of Death in Capital Cases. From Elbridge T. Gerry, Commissioner.

Northampton, Mass. Reports of the Board of Water Commissioners for 1884, 1885, 1887 and 1888. From the Board.

North Carolina Sanitary Association. Proceedings of the First Annual Convention.

Patent Office, British:

Abridgments of Specifications Relating to Bleaching, Dyeing and Printing Calico and other Fabrics and Yarns. 1877–1883.

Name Index. 1888.

Specifications of Inventions. Vols. 73, 76 to 91, of 1887. Vols. 1 to 8, of 1888.

Subject-Matter Index. January to March, 1889.

From the Commissioners.

Pawtucket, R. I. Fourth to Ninth Annual Reports of the Water Commissioners and Superintendent of Water Works.

From the Board of Commissioners.

Peacocke. John M. The Disposal of the Dead.

From the New Mausoleum Company.

Pennsylvania Academy of the Fine Arts. Circular of the Committee on Instruction. 1889–1890. From the Committee.

Pennsylvania. Auditor General's Report on Banks. 1888.

Board of Agriculture, Thirty-ninth and Fortieth Quarterly Reports.

Fire and Marine Insurance Report. 1888.

State Librarian's Report. 1887–1888.

Superintendent of Public Printing and Binding. 1888.

From Hon. Francis A. Osbourne.

Museum and School of Industrial Art.

Circular of the Committee on Instruction.

From the Committee.

State College Agricultural Experiment Station. Bulletin No. 8.

From the Station.

Philadelphia. Second Annual Message of Edwin H. Fitler.

From his Honor the Mayor.

Publishers' Trade List Annual. 1887. From H. C. Baird & Co.

Quarantine Conference. Proceedings held in Montgomery, Ala.

Rochester, N. Y. Annual Reports of the Executive Board for 1882, 1883, 1884–5, 1887 and 1888–9. From the Board.

Royal Dublin Society:

Scientific Proceedings. Vol. 6. Parts 3 to 6.

Scientific Transactions. Vol. 4. Parts 2 to 5.

From the Society.

Royal Society of Canada:

Proceedings and Transactions. Vol. 6. 1888.

From the Society.

Royal Society of New South Wales. Journal and Proceedings. Vol. 22. Part 2. From the Society.

Scientific American. October 1, 1887. June 8 to September 7, 1889.
From Spencer Fullerton.

Scovill & Adams Company. How to make Photographs.
From the Company.

Snyder, Mary Kittera. Life of Governor Snyder. From the Author.

Société des Ingénieurs Civils. Memoires. Mai, 1889. From the Society.

State Department, U. S. Reports from the Consuls. May, 1889.
From Edward Stern & Co.

Soule Photograph Company. Catalogue of Photographic Reproductions.
From the Company.

Sprague Electric Railway and Motor Company. Publications Nos. 1[a], 2[a], 5[a], 6[a], 7[a], 9[a], 10. From the Company.

St. Louis Health Commissioner. Annual Report for the Year ending April, 1889. From the Commissioner.

Storr's School Agricultural Experiment Station. Bulletin No. 4.
From the Station.

Straub's Sub-aqueous Tunnel. Description. From the Author.

Surgeon-General's Office, U. S. A. Index Catalogue of the Library. Vol. 10.
From the Surgeon-General.

Taylor, H. C. Control of the Pacific Water-ways of the Pacific.
From the Nicaragua Canal Company.

Tebbutt's Observatory, Windsor, N. S. W. Report for the Year 1888.
From John Tebbutt.

Technikum Mittweida. Announcement in French, German and English.
Bericht über das zweiundzwanzigste Schuljahr.
From the College.

Todd, J. S. Medicine and Longevity. From the Author.

Trow's New York City Directory. Vol. 100. 1886.
From H. C. Baird & Co.

Troy, N. Y. Sixty-fourth Annual Financial Report.
From the City Controller.

Troy, N. Y. Water Commissioners. Twenty-ninth to Thirty-fourth Annual Reports for Fiscal Years 1883 to 1889. From the Board.

Tucker, Willis G. Report to the State Board of Health of New York.
From the Author.

Union Switch and Signal Company Pocket Reference Book of Interlocking and Signaling Devices. From the Company.

U. S. Bureau of Education:
Circulars of Information. Nos. 1, 2, 3. 1887. Nos. 5 and 6. 1887–88.
Report of the Commissioner. 1886–87. From the Bureau.

U. S. Bureau of Education. Circulars of Information. Nos. 3, 4 and 7 of 1888; No. 1 of 1889. From the Bureau.

U. S. Bureau of Navigation. Nautical Almanac Office. American Ephemeris and Nautical Almanac. 1892. From the Office.

U. S. Bureau of Navigation. Office of Naval Intelligence General Information. Series No. 8. From the Office.

U. S. Bureau of Statistics:

Quarterly Report of the Chief. No. 2. 1888–89.
From the Chief.

Tables showing Production and Consumption of Liquors, etc.
From A. Hosbach.

U. S. Coast and Geodetic Survey. A Bibliography of Geodesy.
From the Superintendent.

U. S. Cremation Company. Opinions on Cremation. From the Company.

U. S. Department of Agriculture:

Division of Chemistry. Bulletin No. 13.
Division of Economic Ornithology, etc. Bulletin No. 1.
Division of Entomology. Periodical Bulletin No. 12.
Division of Statistics. Report No. 63.
Forestry Division. Bulletin No. 3. From the Department.

U. S. Department of Agriculture:

Division of Entomology. Periodical Bulletin, July, 1889.
Farmer's Bulletin, No. 1.
Report of the Statistician, No. 64.
Section of Vegetable Pathology, Quarterly Bulletin, June, 1889.
From the Department.

U. S. Department of Agriculture:

Division of Chemistry. Bulletin No. 21.
Office of Experiment Stations. Bulletin No. 1.
Report of the Statistician. No. 65. From the Department.

U. S. Department of the Interior:

Twenty-four Volumes of Congressional Documents.
From the Department.

U. S. Department of State:

House Journal, second Session fiftieth Congress.
Senate Miscellaneous Documents first Session forty-seventh Congress. Vols. 10 and 11.
Reports from the Counsuls. May, 1889. Contents and Index. Vol. 29. From the Department.

U. S. Department of State:

Commercial Relations. 1880–81 and 1884–85. (Two copies.)
From A. Hosbach.

Commercial Relations. 1886–87.
House Journal. First Session. Fiftieth Congress.
Reports from the Consuls. No. 104. From the Department.
Reports from the Consuls. Nos. 28, 35, 49, 51, 81 to 85 and 89.
From A. Hosbach.

Senate Journal. Second Session. Fiftieth Congress.
From the Department.

U. S. Hydrographic Office. Philadelphia Pilot Chart of the North Atlantic Ocean. August, 1889. From the Office.

U. S. Hydrographic Office, Philadelphia. Publications Nos. 5, 24, 30, 31, 32, 33, 36, 39, 40, 41, 41[a], 41[b], 49, 59, 66, 70, 74, 75, 77, 78, 82, 84 and 86.
From the Office.

U. S. Interstate Commerce Commission. First Annual Report on the Statistics of Railways in the United States.
From the Hon. Augustus Schoonmaker, of New York.

U. S. Patent Office:
Annual Report of the Commissioner of Patents. 1888.
Specifications and Drawings. May and June, 1888.
From the Office.

U. S. Patent Office. Annual Report of the Commissioner of Patents for 1888. From Edward Stern & Co.

U. S. Signal Office:
Report of the Chief Signal Officer for 1888.
Tri-daily Meteorological Record for May, 1878.
From the Office.

U. S. Treasury Department:
Proceedings. Thirty-seventh Annual Meeting of the Board of Supervising Inspectors of Steam Vessels. Part 2.
From the Department.
Report of the Director of the Mint upon the Production of precious Metals. From the Director.

U. S. Treasury Department. Reports of the Supervising Architect. 1885 and 1886. From the Supervising Architect.

University of California. Register, 1888-89 From the University.

University of Pennsylvania. Handbook of Information, concerning the School of Biology. From the University.

U. S. State Department, Papers relating to the Foreign Relations of the United States. 1888. Parts 1 and 2. From the Department.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, September 18, 1889.*]

Hall of the Franklin Institute,
Wednesday, September 18, 1889.

Dr. Isaac Norris, in the Chair.

Present, ninety-four members and thirteen visitors.

Additions to membership since last report, twenty-two.

The report of a special Committee, composed of Professors Edwin J. Houston and L. D'Auria and Mr. Hugo Bilgram, who were appointed to examine a communication submitted for the award of the Boyden

low pressure was accompanied by severe thunder-storms, and the heaviest rainfall of the month.

PRECIPITATION.

The average rainfall for the State during the month of August was 3·24 inches. Considered as a whole, this is about normal, but the distribution was very uneven, and some parts of the State suffered from drouth. The following are the greatest monthly totals in inches: Philadelphia, 7·07; Catawissa, 6·17; Girardville, 6·03; Pottstown, 5·05; West Chester, 4·43; Reading, 4·46. The least were Wellsboro, 0·83; Charlesville, 1·06; Hollidaysburg, 1·37; Altoona, 1·52, and Pittsburgh, 1·88. With but few exceptions, very little rain fell after the middle of the month. Up to this time showers were frequent.

WIND AND WEATHER.

The prevailing winds were from the west; no severe wind-storms occurred. The weather was generally favorable for agricultural pursuits and the growth of all staple crops, with the exception of potatoes. These have suffered from rot. The corn crop will be large.

Average Number.—Rainy days, 8; clear days, 15; fair days, 10; cloudy days, 6.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Charlesville, 1st; Reading, 3d, 14th; Hollidaysburg, 4th; Quakertown, 1st, 2d, 3d, 6th, 13th, 14th; State College, 14th; Phillipsburg, 7th; West Chester, 3d, 5th, 6th, 9th, 13th, 14th; Coatesville, 1st, 3d, 5th, 6th, 9th, 23d; Rimersburg, 15th; Emporium, 14th, 21st; Carlisle, 5th; Swarthmore, 3d, 5th, 7th, 14th; Uniontown, 3d, 4th, 5th, 14th; Huntingdon, 14th, 15th; New Castle, 4th, 21st; Myerstown, 5th; Greenville, 2d, 3d; Pottstown, 3d, 14th; Bethlehem, 2d, 3d, 14th; Philadelphia, 1st, 3d, 9th, 14th, 23d; New Bloomfield, 1st, 4th, 14th; Girardville, 1st, 14th; Selins Grove, 1st, 2d, 3d, 13th; Somerset, 2d, 3d, 4th; Eagles Mere, 20th; Wellsboro, 13th, 21st; Columbus, 1st, 14th; Dyberry, 3d, 6th, 13th, 14th, 21st; Petersburg, 14th; Johnstown, 4th; Le Roy, 1st, 14th, 21st; Blue Knob, 3d, 4th, 10th, 13th.

Frost.—Grampian Hills, 12th; Somerset, 12th, 13th; Wellsboro, 12th, 30th; Dyeberry, 29th; Blue Knob, 11th.

Coronæ.—Greenville, 8th; Dyberry, 4th, 8th.

Solar Halos.—Charlesville, 19th, 23d; Le Roy, 23d.

Lunar Halos.—Hollidaysburg, 6th, 9th, 10th.

WEATHER FORECASTS.

Percentage of local verifications of weather and temperature signals as reported by displaymen for August, 1889:

Weather, 84 per cent.

Temperature, 90 per cent.

...rvice for August, 1889.

...tation.	Number of Days.			Wind.			
				Prevailing Direction.			Observers.
Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
6	9	15	7	N	. . .	N	Oscar D. Stewart, Sgt. Sig. Corps
7	16	12	3	SW	W	S	Rev. A Thos. G. Apple.
8	17	7	7	SW	. . .	SW	C. M. Dechant, C.E.
7	. . .	. . .	. . .	. . .	. . .	. . .	Dr. Charles B. Dudley.
9	14	10	7	NW	NW	NW	A. H. Boyle.
9	17	12	2	W	W	W	Prof. J. A. Stewart.
8	9	10	12	E	W	W	Charles Beecher.
7	. . .	. . .	. . .	SW	. . .	. . .	Geo. W. T. Warburton.
8	14	10	7	W	W	W	J. C. Hilsman.
10	12	13	6	SW	NE	SW	J. L. Heacock.
8	24	6	1	SE	SE	SE	E. C. Lorentz.
6	11	19	1	NW	NW	W	T. B. Lloyd
7	15	13	3	W	W	W	Prof. Wm. Frear.
8	. . .	. . .	. . .	SW	SW	SW	Geo. H. Dunkle.
11	15	12	4	W	SW	SW	Jesse C. Green, D.D.S.
10	16	9	6	W	S	W	W. T. Gordon.
4	20	5	6	SW	W	W	Rev. W. W. Deatrick, A.M.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	C. M. Thomas, B.S.
13	13	12	6	W	W	W	Nathan Moore.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. John A. Robb.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Robert M. Graham.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	R. B. Derickson.
7	14	12	5	S	S	W	J. E. Pague.
10	15	12	4	W	W	W	Frank Ridgway, Sgt. Sig. Corps.
8	1	17	13	NW	NW	NW	Prof. Susan J. Cunningham.
6	16	8	7	SW	SW	SW	Peter Wood, Sgt. Sig. Corps.
7	18	12	1	NW	NW	NW	Wm. Hunt.
4	4	11	16	W	W	W	R. L. Haslet.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Thomas F. Sloan.
5	18	10	3	W	. . .	W	Prof. W. J. Swigart.
8	18	7	6	W	W	W	J. E. Rooney.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. Albert E. Maltby.
8	14	9	8	W	W	W	Wm. T. Butz.
6	22	5	4	W	W	W	Wm. H. Kline.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Geo. W. Bowman, A.M., Ph.D.
8	. . .	. . .	. . .	. . .	. . .	. . .	H. D. Miller, M.D.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Armstrong & Brownell.
7	18	4	9	SE	. . .	SE	Prof S. H. Miller.
7	21	3	7	W	W	W	Charles Moore, D.D.S.
9	22	4	5	W	W	W	Lerch & Rice.
8	16	8	7	NE	NE	NE	Frank Mortimer.
12	13	6	12	SW	SW	SW	Luther M. Dey, Sgt. Sig. Corps.
6	22	5	4	N	N	N	C. L. Peck.
10	17	12	2	W	W	W	E. C Wagner.
6	20	8	3	NW	NW	SW	J. M Boyer,
6	20	9	2	NW	NW	NW	W. M. Schrock.
7	15	9	7	SW	SW	SW	E. S. Chase.
8	10	12	9	N	N	N	H. D. Deming.
11	14	14	3	SW	SW	SW	Wm. Loveland.
8	21	7	3	S	SW	SW	A. L. Runion.
7	13	13	5	W	W	W	Theodore Day.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	John Torrey.
8	19	9	3	NW	. . .	NW	Mrs. L. H. Grenewald.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for August, 1889.

County	Station	Elevation above Sea Level (feet)	Barometer: Mean	Barometer: Highest	Barometer: Lowest	Temperature: Mean	Maximum: Highest	Maximum: Date	Minimum: Lowest	Minimum: Date	Mean of Maximum	Mean of Minimum	Daily Range: Mean	Daily Range: Greatest	Date	Daily Range: Least	Date	Relative Humidity	Dew Point	Precipitation: Total Inches	Number of Days Rainfall	Number of Days: Clear	Fair	Cloudy	Wind, Prevailing Direction: 7 A. M.	2 P. M.	9 P. M.	Observers
Allegheny	Pittsburgh	847	30·076	30·276	29·711	70·2	89·0	31	50·0	12	80·3	60·0	20·3	30·0	31	7·0	9	68·2	57·6	1·88	6	9	15	7	N	...	N	Oscar D. Stewart, Sgt. Sig. Corps
Bedford	Charlesville	1,300	...	...	...	64·9	87·0	31	42·0	12	78·8	53·8	25·0	42·0	31	14·5	14	80·9	58·3	1·06	7	16	12	3	SW	W	S	Rev. A. Thos. G. Apple.
Berks	Reading	304	30·088	30·302	29·821	67·3	87·0	21	46·0	30	81·1	57·2	23·9	40·0	30	12·5	15	90·6	64·3	4·46	8	17	7	7	SW	...	SW	C. M. Dechant, C.E.
Blair	Altoona	1,181	...	...	...	70·4	88·0	3, 22	52·0	28	80·4	60·4	20·0	26·0	13	11·5	9	...	...	1·52	7	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair	Blue Knob	2,100	...	...	...	67·7	86·0	31	50·0	15	75·2	60·3	14·9	26·0	30	9·0	9	...	...	2·40	9	14	10	7	NW	NW	NW	A. H. Boyle.
Blair	Hollidaysburg	947	...	...	...	66·7	90·0	31	41·0	12	81·5	52·6	28·9	41·0	31	18·0	9	84·7	62·6	1·37	9	17	12	2	W	W	W	Prof. J. A. Stewart.
Bradford	Wysox	718	30·089	30·281	29·878	64·4	86·2	21	39·0	29	78·4	52·7	25·7	44·0	30	13·6	20	83·2	58·9	2·07	8	9	10	12	E	W	W	Charles Beecher.
Bradford	Le Roy	875	...	...	...	66·6	83·0	21	48·0	1, 16	75·4	57·0	18·4	26·0	30	7·0	9	...	...	2·08	7	...	...	...	SW	...	...	Geo. W. T. Warburton.
Bucks	Forks of Neshaminy	...	...	...	...	70·1	84·0	21	59·0	30	...	...	...	...	...	...	...	...	...	5·30	8	14	10	7	W	W	W	J. C. Hilsman.
Bucks	Quakertown	536	30·080	30·290	29·750	67·7	87·2	21	45·0	30	80·5	57·6	22·9	38·7	30	14·5	15	83·8	62·5	4·76	10	12	13	6	SW	NE	SW	J. L. Heacock.
Cambria	Johnstown	1,184	...	...	...	65·9	86·0	31	45·5	12, 13	78·4	54·5	23·9	34·0	31	14·0	10	78·0	59·0	3·95	8	24	6	1	SE	SE	SE	E. C. Lorentz.
Cameron	Emporium	1,030	...	...	...	69·2	86·0	30, 31	41·0	29	79·3	52·9	26·4	41·0	30	14·0	15	...	...	3·23	6	11	19	1	NW	NW	W	T. B. Lloyd.
Centre	State College— Agricultural Experiment Station	1,191	30·007	30·305	29·645	66·5	85·0	30	46·0	12, 17	77·1	54·0	22·2	37·0	30	14·0	15	74·6	57·0	3·15	7	15	13	3	W	W	W	Prof. Wm. Frear.
Centre	Phillipsburg	1,350	...	...	...	62·0	88·0	30, 31	38·0	29	82·0	47·0	35·0	43·0	30	10·0	1	...	...	2·40	8	...	...	...	SW	SW	SW	Geo. H. Dunkle.
Chester	West Chester	455	30·075	30·286	29·753	69·9	86·5	21	53·0	28	70·5	62·0	8·5	27·0	30	6·0	27	77·0	62·0	4·43	11	15	12	4	W	SW	SW	Jesse C. Green, D.D.S.
Chester	Coatesville	380	...	...	...	68·9	89·0	21, 31	46·0	30	81·9	58·7	23·2	41·0	30	11·0	1	...	...	3·05	10	16	9	6	W	S	W	W. T. Gordon.
Clarion	Rimersburg	1,500	...	...	...	67·7	86·0	8	52·0	12, 29	76·5	60·3	16·2	28·0	29	6·0	16	...	...	...	4	20	5	6	SW	W	W	Rev. W. W. Deatrick, A.M.
Clarion	Clarion— State Normal School	1,530	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. M. Thomas, B.S.
Clearfield	Grampian Hills	1,450	...	...	...	65·6	86·0	31	40·0	12	76·7	57·0	19·7	36·0	31	10·0	15	...	...	4·00	13	13	12	6	W	W	W	Nathan Moore.
Clinton	Lock Haven	560	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. John A. Robb.
Columbia	Catawissa	401	...	...	...	67·0	83·5	21	49·0	21, 30	...	...	...	...	...	...	...	...	...	6·17	...	...	...	...	...	...	...	Robert M. Graham.
Crawford	Meadville— Allegheny College	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. B. Derickson.
Cumberland	Carlisle	480	...	...	...	72·9	95·0	30	51·5	12	85·4	63·2	22·2	33·0	30	1·5	23	71·2	65·1	2·49	7	14	12	5	S	S	W	J. E. Pague.
Dauphin	Harrisburg	361	30·106	30·337	29·715	68·6	85·0	21, 31	53·0	28	78·9	60·7	18·2	28·0	30	5·0	23	78·3	61·2	3·58	10	15	12	4	W	W	W	Frank Ridgway, Sgt. Sig. Corps.
Delaware	Swarthmore— Swarthmore College	190	30·063	30·240	29·770	70·1	87·4	21	54·0	15, 16	79·9	61·9	18·0	29·4	30	8·2	26	79·0	63·0	3·52	8	1	17	13	NW	NW	NW	Prof. Susan J. Cunningham.
Erie	Erie	681	30·080	30·280	29·740	67·0	81·0	19	52·0	12	75·0	60·0	15·0	23·0	7	7·0	9	68·0	57·0	2·26	6	16	8	7	SW	SW	SW	Peter Wood, Sgt. Sig. Corps.
Fayette	Uniontown	1,000	30·061	30·185	29·831	69·1	87·0	21	46·0	12	79·2	57·9	21·3	30·0	31	11·0	14	79·5	61·0	3·86	7	18	12	1	NW	NW	NW	Wm. Hunt.
Forest	Tionesta	1,057	...	...	...	62·6	100·0	22	45·0	12	80·6	56·3	24·3	45·0	22	6·0	21	...	...	2·40	4	4	11	16	W	W	W	R. L. Haslet.
Fulton	McConnellsburg	875	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Thomas F. Sloan.
Huntingdon	Huntingdon— The Normal College	650	...	...	...	67·6	90·0	31	43·0	12	81·4	53·8	27·6	39·0	27	15·0	2	...	...	1·80	5	18	10	3	W	...	W	Prof. W. J. Swigart.
Huntingdon	Petersburg	700	...	...	...	68·6	96·0	31	42·0	13	79·6	54·6	25·0	44·0	31	2·0	23	...	...	3·12	8	18	7	6	W	W	W	J. E. Rooney.
Indiana	Indiana— State Normal School	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Albert E. Maltby.
Lawrence	New Castle	932	...	...	...	69·9	91·0	31	42·0	29	80·6	51·3	29·3	46·0	31	14·0	5	...	...	2·28	3	14	9	8	W	W	W	Wm. T. Butz.
Lebanon	Myerstown	474	30·067	30·265	29·781	68·7	89·1	31	47·1	30	81·2	57·4	23·8	39·2	30	11·0	23	83·2	62·5	3·07	6	22	5	4	W	W	W	Wm. H. Kline.
Lebanon	Annville— Lebanon Valley College	339	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Geo. W. Bowman, A.M., Ph.D.
Luzerne	Drifton— Drifton Hospital	1,655	...	...	...	64·1	84·0	14	44·0	29	77·8	55·8	22·0	35·0	30	6·0	10	...	...	4·77	8	...	...	...	...	...	...	H. D. Miller, M.D.
McKean	Smethport	1,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell.
Mercer	Greenville— Thiel College	1,000	30·044	30·307	29·684	63·6	83·9	26	38·7	12	78·8	53·4	25·4	41·0	29	7·1	9	87·4	56·9	1·83	7	18	4	9	SE	...	SE	Prof. S. H. Miller.
Montgomery	Pottstown	150	...	...	...	72·0	88·0	21	50·0	30	81·4	61·5	19·9	36·0	30	12·0	15	80·0	64·5	5·05	7	21	3	7	W	W	W	Charles Moore, D.D.S.
Northampton	Bethlehem	360	...	...	...	71·1	86·0	21, 31	46·0	30	80·1	59·2	20·9	38·0	30	12·0	3	73·0	62·0	4·10	9	22	4	5	W	W	W	Lerch & Rice.
Perry	New Bloomfield	400	...	...	...	67·2	90·0	31	40·0	7	81·2	53·8	27·4	40·0	31	11·0	23	...	...	2·75	8	16	8	7	NE	NE	NE	Frank Mortimer.
Philadelphia	Philadelphia	117	30·096	30·310	29·760	72·8	88·0	22	57·0	28	80·9	64·7	16·2	26·0	30	9·0	26	72·6	63·0	7·07	12	13	6	12	SW	SW	SW	Luther M. Dey, Sgt. Sig. Corps.
Potter	Coudersport	1,670	...	...	...	65·6	85·0	30	38·0	29	76·3	49·6	26·7	44·0	29	12·0	14	82·2	59·2	3·80	6	22	5	4	N	N	N	C. L. Peck.
Schuylkill	Girardville	1,000	30·105	30·285	29·775	67·0	95·0	2	48·0	12, 28	78·0	56·4	21·6	37·0	2	13·0	3	...	...	6·03	10	17	12	2	W	W	W	E. C. Wagner.
Snyder	Selins Grove	445	...	...	...	71·8	87·0	21	52·0	12, 30	78·4	62·8	15·6	61·0	26	50·0	16	76·7	61·7	6·00	6	20	8	3	NW	NW	SW	J. M. Boyer.
Somerset	Somerset	2,250	...	...	...	62·7	83·0	29	41·0	13	75·2	52·1	23·1	43·0	29	10·0	2	87·0	59·2	3·35	6	20	9	2	NW	NW	NW	W. M. Schrock.
Sullivan	Eagles Mere	2,060	30·109	30·337	29·901	64·8	79·0	30	48·0	12, 29	72·2	55·7	16·5	26·0	29	5·0	14	77·2	57·2	2·82	7	15	0	7	SW	SW	SW	E. S. Chase.
Tioga	Wellsboro	1,327	30·055	30·317	29·652	62·3	86·0	21	38·0	30	73·6	51·8	21·8	38·2	30	6·0	14	68·2	56·4	·83	8	10	12	0	N	N	N	H. D. Deming.
Warren	Columbus	1,410	...	...	...	63·8	92·0	30	37·0	12	78·7	48·8	29·9	52·0	30	7·0	9	79·2	54·4	2·37	11	14	14	3	SW	SW	SW	Wm. Loveland.
Washington	Canonsburg	950	...	...	...	67·9	84·0	21, 26	45·0	16	78·1	57·7	20·4	...	...	...	...	73·2	58·5	1·64	8	21	7	3	S	SW	SW	A. L. Runion.
Wayne	Dyberry	1,100	...	...	...	61·2	84·0	30	36·0	29	75·5	49·2	26·3	46·0	30	9·0	5	...	...	2·85	7	13	13	5	W	W	W	Theodore Day.
Wayne	Honesdale	1,000	...	...	...	62·0	80·0	2, 21	39·0	30	72·3	50·8	21·5	36·0	30	4·0	15	...	...	2·60	...	...	...	...	...	...	...	John Torrey.
York	York	385	30·074	30·277	29·798	70·2	88·0	31	45·5	18	81·3	58·9	22·4	34·5	18	7·5	7	76·6	62·0	2·83	8	19	9	3	NW	...	NW	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

New Castle.	Greenville.	Columbus.		Dyberry.	Coudersport.	Honesdale.	Quakertown.	Swarthmore.	Philadelphia.	Scisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Nesham'y.	Germantown.	Point Pleasant.	Bethlehem.	Canonsburg.
. .	·03	·29		·31	·40	·33	·50	·72	·60	·45	·05	·37	·90	·05	·15	. .	. .	·70	·37	·10
. .	. .	. .		. .	. .	·07	. .	. .	·03	. .	. .	·31	. .	·11	. .	·46	·38	·20	·40	. .
·47	·19	·04		·61	. .	·16	·08	. .	·22	·37	·35	·05	·13	·34	1·14	1·85	·98	. .	. .	·40
. .	·11	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·15
·33	. .	·04		·65	1·00	·54	·52	·84	1·02	·20	·38	·45	·37	·53	·40	·41	·74	·24	·50	·77
. .	. .	. .		. .	. .	. .	·02	. .	. .	·07	·06	·04	·09	·06	. .	. .	. .	·01	·04	. .
. .	. .	. .		. .	. .	. .	. .	·11	·06	. .	. .	. .	. .	. .	. .	·25	1·00	. .	. .	. .
. .	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·13	·51	1·17		·23	. .	·12	. .	·60	·19	. .	. .	·30	. .	. .	·24	. .	. .	. .	. .	. .
·32	. .	·04		. .	·70	. .	·22	·04	·17	·23	·15	·16	·22	. .	·37	·29	·18	. .	·21	·15
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .		·07	. .	·03	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·38	. .	. .		. .	. .	. .	1·09	. .	·01	1·43	. .	2·00	·14	. .	. .	. .	. .	. .	1·65	. .
·15	·90	·33		·91	·80	1·35	2·21	·85	1·25	1·40	2·67	1·41	2·64	2·56	1·93	1·44	1·72	2·53	·87	. .
·25	·03	·03		. .	·30	. .	·02	·02	1·54	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	·06	·04		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	·04		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	·01		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	·04	·06	·20	. .	·05	. .	. .	·03	. .
·25	. .	·34		. .	·60	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·07	. .	·07
.	. .	. .		·07	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .		. .	. .	. .	·03	. .	1·51	. .	. .	. .	. .	·43	. .	. .	. .	. .	·03	. .
.	. .	. .		. .	. .	. .	·07	·34	·38	. .	·17	. .	·33	. .	. .	·55	1·60	. .	. .	. .
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·43	. .	. .	. .	. .	. .
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
28	1·83	2·37	1·	2·85	3·80	2·60	4·76	3·52	7·07	4·15	3·83	5·13	4·88	4·28	4·66	5·30	6·60	3·75	4·10	1·64

T. F. T.

PRECIPITATION FOR AUGUST, 1889.

Date	New Castle	Greenville	Columbus	Pittsburgh	Uniontown	Tionesta	Clarion	Indiana	Johnstown	Smethport	Somerset	Grampian Hills	Emporium	Blue Knob	Phillipsburg	Petersburg, Hu. Co.
1		.03	.29			.30						.05			.52	.09
2					.28							.06				
3	[illegible]	.19	.04		1.05				.21		.49	.05	.15	.30		.15
4		.11		.06	.42				.03		.49	.03			.02	
5			.04	.38	.55	.30			1.08		.07	.30	.44	.70	.20	.30
6											1.21					.05
7															.62	
8																
9	[illegible]	.51	1.17						.12			.05	.19	.20		.09
10	[illegible]		.04	.86	.39				.73			.08		.60	.23	.50
11																
12																
13				.01												
14	[illegible]	.90	.33	.35	.96	1.30			1.67		1.02	2.77	1.75	.40		1.50
15	[illegible]	.03	.03						.08		.07	.05		.10	.65	.44
16		.06	.04									.09	.11			
17	[illegible]		.04									.02			.06	
18			.01													
19																
20																
21			.34	.22	.21	.50						.45	.59	.10		
22									.03						.10	
23																
24																
25																
26																
27																
28																
29																
30																
31																
Total	[illegible]	1.83	2.37	1.88	3.86	2.40	. .	. .	3.95	. .	3.35	4.00	3.23	2.40	2.40	3.12

Date	Huntingdon	Hollidaysburg	Altoona	Charlesville	McConnellsburg	State College	York	New Bloomfield	Carlisle	Wellsboro	Nisbet	Harrisburg	Selins Grove	LeRoy, Bradf'd Co.	Eagles Mere
1		.02	.05				.56	1.00	1.50			.50	1.00	.74	.39
2														.07	
3		.15	.08	.19		.02			.05			.04	.13	.01	
4		.01							.01						.46
5	.46	.38	.33	.29		.41	.42	.60	.25	.24		.54	.44	.65	
6		.01					.21	.05				.28	.05		
7			.03												
8															
9	.03	.03		.16		.08	.01	.10		.10		.06	.06	.08	.34
10	.39	.14	.28			.34	.64	.23	.18			.12	.30		
11															
12															
13						.02				.08					
14	.45	.61	.65	.26		2.25	.25	.62		.10		.98	3.91	.49	.58
15	.47	.02	.10				.70	.05	.40				.06		.42
16									.10	.05					
17				.02											
18															
19										.05					
20										.05					.35
21										.16					.28
22				.04		.03								.04	
23				.10				.10				.06	.05		
24							.04								
25															
26															
27															
28															
29															
30															
31															
Total	1.80	1.37	1.52	1.06	. .	3.15	2.83	2.75	2.49	.83	. .	2.58	6.00	2.08	2.82

Date	Myerstown	Wysox	Catawissa	Girardville	Drifton	Reading	Pottstown	West Chester	Coatesville	Dyberry	Coudersport	Honesdale	Quakertown	Swarthmore
1	.50	.43		.29	.22	1.17	.20	.58	.32	.31	.40	.33	.50	.72
2												.07		
3		.25	.55	.04		.29	1.33	.13	.82	.61		.16	.08	
4		.58		.08										
5	1.08	.08		.61	.57	.50	.60	.57	.51	.65	1.00	.54	.52	.84
6			.41	.03		.07	.10	.04	.35				.02	
7								.16	.02					.11
8														
9			.40	.07	.11	.11		.18	.08	.23		.12		.60
10	.38		.80	.56	.33	.33	.20	.20	.34		.70		.22	.04
11														
12										.07		.03		
13		.38	1.20	.24									1.09	
14	.55	.12	2.75	4.03	3.42	1.88	2.50	.84	.46	.91	.80	1.35	2.21	.85
15	.41				.04	.11					.30		.02	.02
16														
17														
18														
19														
20		.17			.03									
21		.06		.08							.60			
22					.05					.07				
23	.15		.06					.05	.08				.03	
24							.12	1.65	.07				.07	.34
25								.03						
26														
27														
28														
29														
30														
31														
Total	3.07	2.07	6.17	6.03	4.77	4.46	5.05	4.43	3.05	2.85	3.80	2.60	4.76	3.52

Date	Philadelphia	Scisholtzville	Frederick	Ottsville	Smith's Corner	Doylestown	Lansdale	Forks of Neshamy	Germantown	Point Pleasant	Bethlehem	Canonsburg
1	.69	.45	.05	.37	.90	.05	.15			.70	.37	.15
2	.03			.31		.11		.46	.38	.20	.40	
3	.22	.37	.35	.05	.13	.34	1.14	1.85	.98			.40
4												.15
5	1.02	.20	.38	.45	.37	.53	.40	.41	.74	.24	.50	.77
6		.07	.06	.04	.09	.06				.01	.04	
7	.06							.25	1.00			
8												
9	.19			.30			.24					
10	.17	.23	.15	.16	.22		.37	.29	.18		.21	.15
11												
12												
13	.01	1.43		2.00	.14						1.65	
14	1.25	1.40	2.67	1.41	2.64	2.56	1.93	1.44	1.72	2.53	.87	
15	1.54											
16												
17												
18												
19												
20				.04	.06	.20		.05			.03	
21										.07		.07
22												
23	1.51					.43					.03	
24	.38		.17		.33			.55	1.60			
25							.43					
26												
27												
28												
29												
30												
31												
Total	7.07	4.15	3.83	5.13	4.88	4.28	4.66	5.30	6.60	3.75	4.10	1.64

T. F. T.

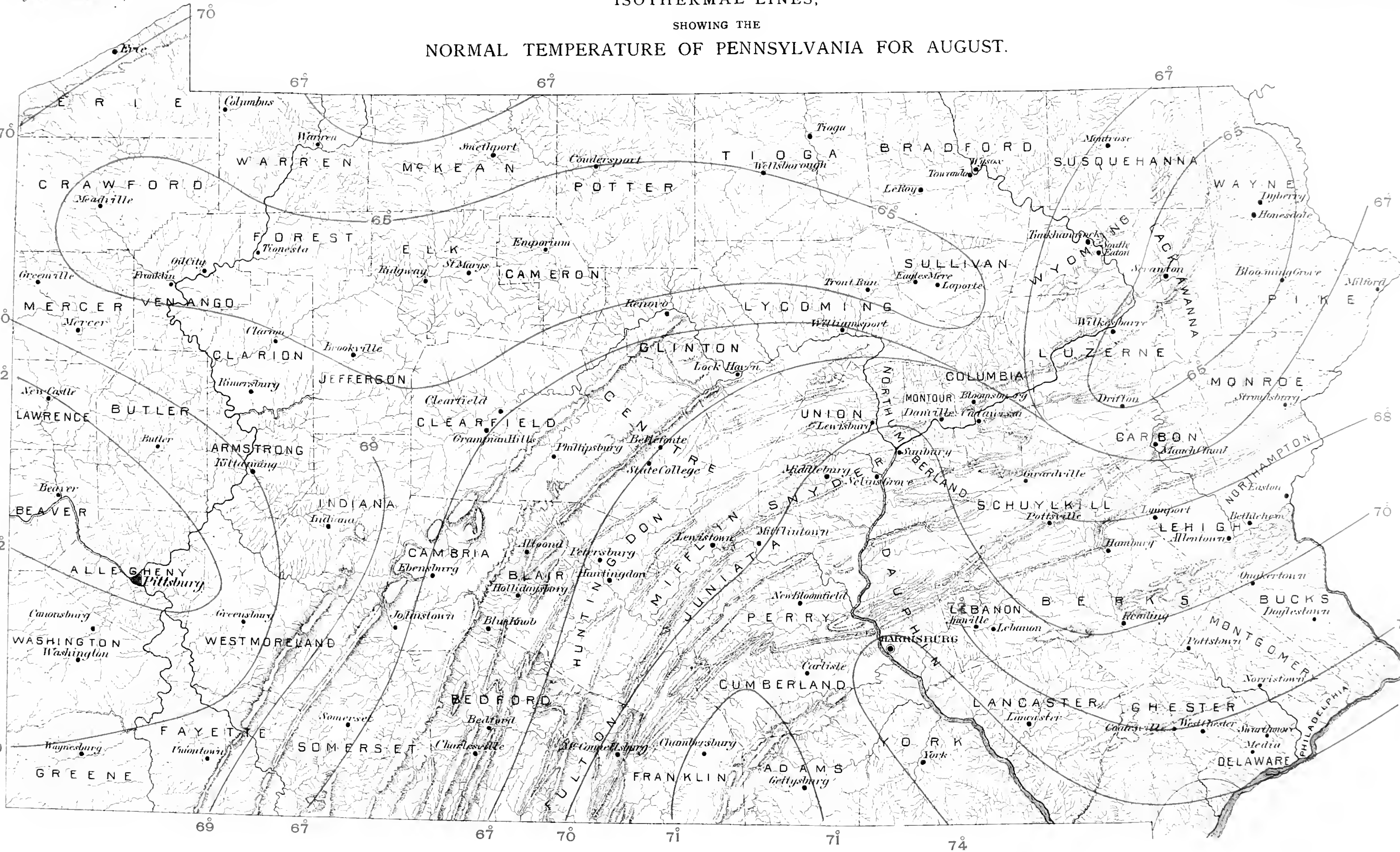
TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.

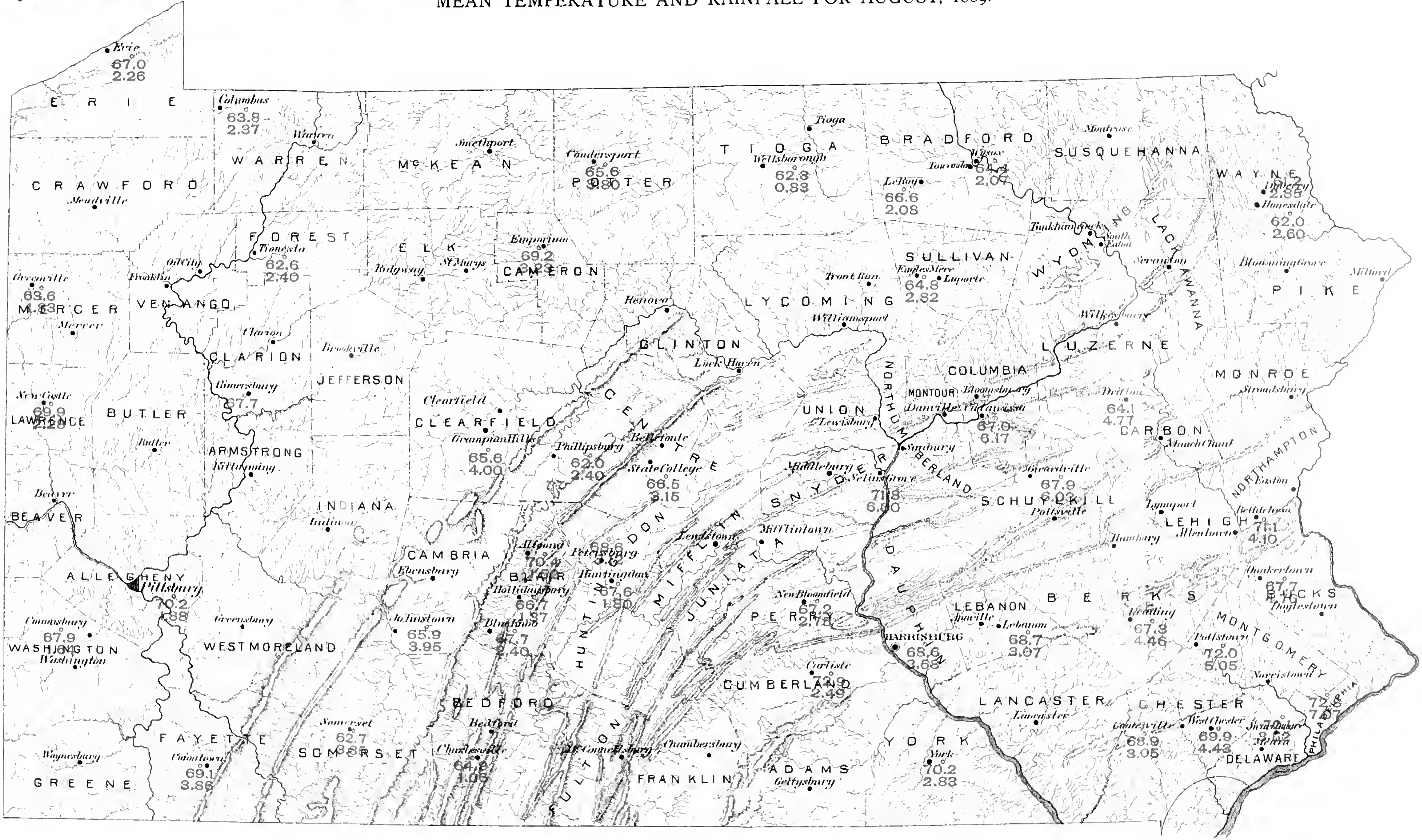
ISOTHERMAL LINES,

SHOWING THE

NORMAL TEMPERATURE OF PENNSYLVANIA FOR AUGUST.



MEAN TEMPERATURE AND RAINFALL FOR AUGUST, 1889.



Displayman.	*Station.*
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.
W. S. Ravenscroft,	Hyndman.
R. C. Schmidt & Co.,	Belle Vernon.
Jesse R. Brown,	Lehmasters.
H. W. Mullen,	Centre Valley.
Mayer Bros.,	Bloomsburg.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVIII. NOVEMBER, 1889. NO. 5.

THE ANEROID BAROMETER, ITS VARIOUS FORMS, ITS THEORY AND ITS USE, WITH SPECIAL REFERENCE TO THE DETERMINATION OF ALTITUDES.

BY E. A. GIESELER, C.E.

I. GENERAL DISCUSSION.

The motor of all aneroids consists in an hermetically sealed box, the air of which has been exhausted as completely as practicable, and the flexible sides of which will consequently perform certain motions, when the pressure of the atmosphere changes. These motions are, however, too small to be perceived by the unaided eye, and they are, therefore, transmitted to a suitable mechanism, by means of which they are magnified to such an extent that they can be discerned and measured.

The invention of the aneroid dates back to the beginning of this century, one of the oldest forms being the one con-

structed by Bourdon, in which the box has the shape of a tube sealed at both ends, and bent into the shape of a circle. A small open space remains between the two ends, and diametrically opposite this gap the tube is fastened to a supporting plate. The cross-section of this tube is either rectangular or oval, and the direction of its greatest height or diameter stands at right angles to the plane of the circle into which the tube has been bent, which is parallel to the supporting plate.

When compressed air or steam is admitted into such a tube, the inner pressure thus created will have the tendency to straighten it, on account of the excess of pressure exercised on the *greater* area of the *outer* circular side as compared with the *smaller* area of the *inner* circular side. Any increase of the inner pressure will result in a further flattening of the circle into which the tube has been bent, while a decrease of it will cause such curve to be sharpened.

Precisely the reverse will take place, when the tube has been exhausted, because then the acting force, instead of being an *inside* pressure, will be the *outside* pressure of the atmosphere. The tube being held as described before at one point only, which is situated diametrically opposite the opening between the two ends, it is evident that the changes of form of the curve must result in movements of these ends; under the influence of high atmospheric pressure they will approach each other, while a decrease of pressure will widen the gap between them. The movements of the ends are transmitted by a simple arrangement to a hand pointing on a graduated dial. They are magnified either by levers acting on the *short* arm of the hand or pointer, or, when the latter is mounted centrally, by means of a toothed wheel and pinion.

This form of the aneroid has nowadays been entirely superseded by others, in which the vacuum box has the shape of a flat cylinder, into the upper and lower circular ends of which concentric grooves are pressed in order to equalize the motions performed by them under the influence of the varying atmospheric pressure. To the side of the vacuum box is soldered a small tin pipe, through which the

air is exhausted. After this has been done the pipe is sealed and the upper and lower ends of the box are now deflected towards its interior by the pressure of the atmosphere, the amount of such deflections for a given pressure being dependent on the strength of the plates. This must be sufficient to prevent too great a departure from the horizontal positions, in order not to strain the plates beyond their limit of elasticity. The movements are, therefore, necessarily small; a fall of $\frac{1}{100}$ of an inch in the mercurial barometer corresponding to an approach of about $\frac{1}{20000}$ of an inch of the plates of the vacuum chamber.

II. THE NAUDET ANEROID.

To measure such exceedingly small quantities, one class of modern aneroids is provided with an ingenious mechanism invented by Vidi and later improved by Naudet, the main parts of which are shown in *Fig. 1*.

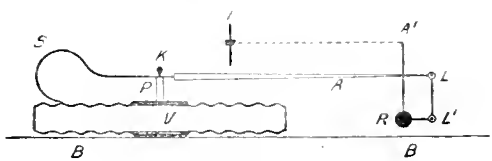


FIG. 1.

To the base or foundation plate *B B* are firmly attached a laminated spring *S* and the vacuum chamber *V*. The latter carries upon its centre an upright pillar *P*, which passes through an opening in the spring and presses on its upper side by means of the knife edge *K*. An elastic system is in this way formed by vacuum chamber and spring and the pulsations of the former will be imparted to the latter. The horizontal arm *A* is firmly attached to the spring and will therefore follow its movements. These will appear in a magnified scale at the end *L* and are transmitted by the two links *L* and *L'* to the rocker shaft *R*, which turns in bearings attached to the base plate, but not shown in the diagram. The turning motions of *R* are further magnified by the arm *A'* and thence transmitted by a small chain *C* to the central shaft *I*, which carries the index pointer. The required tension on the chain is produced by a spiral spring acting on

the central shaft. This spring and the bearings for the central shaft are not shown in the diagram.

The graduation of the dial on which moves the index pointer, like the hand on a watch dial, is made to correspond as nearly as possible with the reading of the mercurial barometer, and, like the latter, is expressed in millimetres or in inches. Perfect accuracy in this respect cannot be attained: there will always be required a certain correction for graduation. This and the corrections for temperature are the most important ones for practical work and will be discussed further below.

As apparent from the above, the use of the Naudet aneroid is very simple; in fact, the handling and reading of no instrument could be simpler. But this advantage is obtained by means which, in themselves, constitute the source of undoubted defects. The magnification and the measuring of the small movements of the vacuum chamber are performed by means of an exceedingly delicate mechanism, which is liable to get out of order unless great care is exercised in handling and transporting the instrument. Such constant and unremitting care, however, cannot be exercised under all circumstances, especially not in our country where the aneroid, in the hands of the railroad engineer for instance, is frequently subjected to swift transportation on horseback over many miles of rough country, the jolting and jarring of which are almost certain to prove injurious to the instrument. Even ordinary transportation in good packing frequently puts a Naudet out of working order, and no dealer in these instruments can warrant their safe arrival at the end of a long railroad journey.

Hence the frequent complaints of engineers, who have bought instruments in New York or some other great centre and to their dismay find them giving out completely when needed, a calamity which will be all the more annoying, when it happens, as it naturally often does, at a place far removed from any facilities for repairing.

Aside from such heavy shocks, which may at once render a Naudet perfectly useless, an instrument actually used in the field is necessarily exposed to small shocks, which even

the most careful and experienced observer cannot entirely avoid, and the continuance of which tends to produce a slackening of the mechanism. The gradual deteriorating from this cause of Naudet aneroids, during their use in the field, is a well-established fact, even when they are in the hands of the best observers (Report of Mr. J. Campbell. R. N., published in *U. S. Monthly Weather Review*, September 1879).

Finally a very important defect should be mentioned here, which may not inadequately be termed the "elastic reaction" of the instrument and which asserts itself in the tardiness with which the mechanism accommodates itself to changes in atmospheric pressure.

C. Kroeber, in his experiments with Naudet aneroids (*Zeitschrift für Vermessungswesen*, Heft. 8, 1881), has found that it took the instrument about two days to accommodate itself to a change of pressure corresponding to five inches of the mercurial column, the readings taken immediately after the pressure had been changed differing nearly two-tenths of an inch from the final ones. If not considered in the case of a measurement of altitudes this difference would have constituted an error of about 200 feet in about 5,000 feet.

It is true that the quality of "elastic reaction" in a measure is common to all aneroids, but it is especially pronounced in the Naudet, on account of its peculiar and complicated mechanism. As apparent from the above, the latter circumstance constitutes the origin of several serious defects, the only remedy for which, evidently consists in a simplification of the mechanism.

But it is as evident that such a simplification could not be attained, without at the same time sacrificing in a measure the ease and simplicity of handling and reading the instrument. Some of the work, which in the Naudet aneroid is performed by the complicated mechanism itself, in an instrument of simpler construction necessarily had to devolve on the observer. The difficulty then, consisted in harmonizing, in the most advantageous manner possible, requirements, the fulfilment of one of which impaired the fulfilment of the other.

III. THE GOLDSCHMID ANEROID.

This problem was solved after years of experiments by J. Goldschmid, of Zurich, about 1860, through an entirely novel construction, in which the movements of the vacuum chamber are measured by a micrometer screw acting on a peculiar lever arrangement, combined with optical magnification. In the following diagram, the left-hand side of which represents a section through the instrument, the exceedingly simple arrangement of the working parts is clearly shown.

To the centre of the top of the vacuum chamber *A A* is soldered a crank-shaped piece, which ends at one extremity in an upward turned knife edge; the latter supports the main lever *e e''*, which in its turn swings freely around the fulcrum *e''*. The movements of the vacuum chamber are

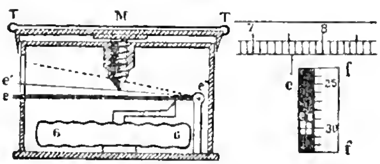


FIG. 2.

transmitted by the supporting knife edge to the main lever, the end *e* of which carries a small hammer-shaped piece. On the face of this is marked a horizontal index line, which will move vertically up and down, according to the varying pressure of the atmosphere. These movements take place alongside of a vertical ivory scale, which serves to measure them and which bears a graduation corresponding to the full inches of the mercurial column (see the right-hand side of *Fig. 2*, which shows the hammer and scale in front view).

While from the ivory scale the full inches only of the aneroid reading can be taken, the following arrangement serves for measuring the tenths and hundredths of inches. A fine and light spring *e' e''* is soldered to the main lever near the end *e''*; at the other end *e'* it carries a small hammer, similar to the one described before; when no pressure is exercised on the spring this hammer is held by the elas-

ticity of the same a little above the top of the hammer c, standing at the same time sideways of it.

To the cover T T, of the brass case enclosing the entire apparatus, is attached the micrometer screw M, which can therefore be screwed up or down by turning such cover. The lower pointed end of the micrometer acts on the spring $c' c''$, and when a reading is to be taken it is screwed down until the spring has been depressed so much that the index line of c' coincides with the index line of c.

It is at once clear that this position of the two hammers, which is shown in the diagram, corresponds to a certain distance between the point of the micrometer screw and the main lever, a distance which remains the same for all the various positions into which the main lever may be raised or lowered by the movements of the vacuum box. The point up to which the micrometer screw has to be screwed down, in order to make the two index lines coincide, is thus made a measure of the position in altitude of the main lever. This measure is read by means of a graduation engraved on the circumference of the cover and dividing the same into 100 equal parts, each of which corresponds to one hundredth of an inch of mercurial barometer height. The graduation is so wide that thousandths can easily be estimated.

The *modus operandi* then, in using the Goldschmid aneroid, is as follows:

The outer morocco case of the instrument is opened, and holding the latter in a horizontal position the cover is screwed down, while at the same time the two little hammers, protruding from the brass case through a window-like opening, are observed by means of the attached microscope. When the upper hammer is seen to commence moving downward, then the micrometer screw should be turned carefully and slowly, and when the two index lines coincide it is stopped entirely. Before such coincidence is obtained the instrument should be tapped lightly on the top, in order to eliminate any inertia of the mechanism. It is very important that this tapping should always be done in the same position of the hammers, because if, for instance, it is

done sometimes before coincidence and at other times at coincidence, then differences in the readings will be the consequence, that may amount to as much as $\frac{1}{100}$ of an inch. In order to insure uniformity in this respect it is advisable to make it a standing rule, *to tap when the lower edge of the upper hammer arrives at coincidence with the index line;* thence forward the screw should be turned very carefully, avoiding all further shocks.

IV. DISCUSSION OF THE CORRECTIONS.

In order to find, from the reading obtained by a Naudet or a Goldschmid aneroid, the height of the mercurial column of 32° Fahrenheit temperature, corresponding to the same pressure, three corrections are required, viz: for temperature, for graduation and for position, the latter not being required when the instrument is used for measuring altitudes only.

Let A represent the reading of the aneroid, T the temperature of the instrument in degrees Fahrenheit, and A_0 the reading that would have been obtained if the temperature had been 32° Fahrenheit, then we have, concerning the correction for temperature:

$$A_0 = A + \alpha\, F(t) \tag{1}$$

wherein α is the coefficient for temperature, the structure of the function t for the present remaining undecided.

Regarding the correction for graduation, aneroids are generally set so, that at a reading of thirty inches there is coincidence between them and the mercurial barometer, after the correction for temperature has been made on both. The coefficient of graduation is the difference between one inch of the mercurial column and one inch of the aneroid graduation; this—multiplied by the difference, thirty—reading, clearly renders the correction for graduation. Hence we have

$$B_0 = A_0 + \beta\,(30 - A_0)$$

wherein B_0 the height of the mercurial column reduced to the freezing point and β the coefficient for graduation.

The above described coincidence between the aneroid and the mercurial at thirty inches, even if completely attained, rarely lasts long, and in order to compensate for this a constant must be added to the right-hand side of the above equation. This constant is the correction for position and is generally designated by the letter C; we therefore have finally

$$B_0 = A_0 + \beta\,(30 - A_0) + C \qquad (2)$$

Proceeding now to discuss the structure of the above function of t, equation (1), it should be remembered that each change in temperature causes two different forces to act on the mechanism. In the first place, the corrugated surface of the vacuum chamber having a greater area than corresponds to its circumference, is expanded too much by a rise in temperature, and this excess of expansion causes a *depression* of the surface. The reason why the latter is not *raised* instead of being *depressed* is to be found in the circumstance, that in all good instruments it is bent slightly towards the interior, so that, even under a minimum of atmospherical pressure, it will only rise about to the horizontal, but never bulge outward beyond this.

The second force is created by the small quantity of air, present in all so-called vacuum chambers, being expanded by the additional heat imparted to it, thus exercising an inside pressure, that tends to counteract the first described force.

In the Naudet aneroid the chamber is exhausted as much as possible, and the inside pressure caused by a rise of temperature under all ordinary circumstances is therefore much smaller than the force caused by surface expansion of the box and pressing such surface towards the interior. These instruments will therefore be affected by a rise of temperature in the same way as by an increase of atmospherical pressure, that is, the reading of the instrument will become higher. Hence the correction for temperature in Naudet aneroids is subtractive for all temperatures above the freezing point and additive for all temperatures below.

From what has been said, it is clear that the second or inside force can be increased by admitting additional air

into the vacuum chamber, and it was suggested by Professor Kohlrausch, that in this way the two forces might be made to counterbalance each other entirely, thus reducing the correction for temperature to nothing. The impossibility of this was demonstrated by Professor Weilenmann, whose extensive theoretical and experimental researches on this subject rendered the following results:

(1) When the temperatures are plotted as ordinates and the corrections pertaining to them as abscisses, then a parabola is obtained.

(2) The apex of this parabola can be shifted to lower or higher temperatures, by respectively increasing or diminishing the amount of air contained in the chamber.

Although these principles differ theoretically from Bauernfeind's opinion, that the correction for temperature increases in direct proportion to the temperature, yet for Naudet aneroids, with highly exhausted chambers, there is no great practical difference between both assertions. This will be seen clearly from the following diagram, in the left-hand part of which a correction curve for temperature is shown, that was obtained by Professor Weilenmann from actual tests with an aneroid, the chamber of which was exhausted as completely as possible. For all such temperatures as are likely to occur in practical work, this curve does not depart materially from a straight line, which latter would be the expression of Bauernfeind's law in the diagram.

TEMPERATURE IN DEGREES CELSIUS.

Professor Weilenmann's above named principles have been utilized in the construction of the Goldschmid aneroid for the purpose of reducing as much as possible the correction for temperature. An amount of air corresponding to a few inches of the mercurial column is admitted into the vacuum chamber, thereby shifting the apex of the parabola to near the freezing point and consequently reducing to practically nothing the corrections in that vicinity. An example of this is given in the right-hand part of *Fig. 3*, where a correction curve is shown for a vacuum box, which contained an amount of air corresponding to six inches

of the mercurial column. The characteristic differences between this curve and the high vacuum curve in the left-hand part of the same diagram, are at once apparent and strikingly to the advantage of the former. Under the influence of high temperatures the inner pressure now exceeds the force, bending the surface towards the interior, in other words, such influence will act on the Goldschmid aneroid like a *decrease* of atmospheric pressure.

Summing up, we find that the correction for temperature for the Goldschmid instruments in the vicinity of the freezing point is practically nothing, again, that as a general rule it is everywhere considerably less than for the Naudet aneroid or for the mercurial barometer, and, finally, that what little there is of it, is *additive*.

While the Goldschmid aneroid is not claimed to be entirely compensated for temperature, the corrections for the latter are doubtless in it reduced to very small quantities, a table of which, resulting from careful tests made by the manufacturer, accompanies every instrument.

For some of the Naudets in the market, entire compensation is claimed, but if the practical test is made, probably one out of ten will be actually found so, while the corrections of most of the rest will exceed those of the Goldschmid, without the purchaser being furnished with a table for them.

A simple and very effective method of ascertaining the correction for temperature consists in the use of warm, tepid and cold water baths, and finally the ice bath. By their means the inner temperature of an instrument can be varied from the freezing point upward, to say 100° or more. The observations must of course be made together with observations on a mercurial, and both are recorded in about the following way:

Mercurial Thermometer.	Aneroid.			
B_0	A	t	A'	$29.094 - A'$
1	2	3	4	5
29·149	29·073	67·0	29·016	0·078
29·148	29·070	66·2	29·014	0·080
29·143	29·073	75·0	29·022	0·072
29·132	29·074	74·4	29·035	0·059
etc.	etc.	etc.	etc.	etc.

In this table the letters at the heads of the various columns have the following meaning:

(1) B_0 is the reading of the mercurial barometer in inches and decimals, as reduced to the freezing point.

(2) A is the reading of the aneroid under the same pressure.

(3) t is the inner temperature of the aneroid in degrees Fahrenheit and decimals.

(4) A' is what the aneroid would have read, if the pressure during the entire series of observations had constantly remained at $B'_0 = 29·094$ (this being the average of all the B_0 of the entire series).

The value of A' is found in the following manner: In the case of the actual example cited here a preliminary determination had been made, showing that 1·000 inch of the aneroid corresponded to 0·970 inch of the mercurial column. If, therefore, in the case of the first observation for instance, the mercurial barometer had read 29·094 (instead of 29·149), that is 0·055 less than it actually did read, then the aneroid would clearly have read $\frac{100}{97} \times 0·055 = 0·057$ less than it actually did read, that is to say $29·073 - 0·057 = 29·016$. The difference between the value $29·094 - A'$ as found for the freezing point and as found for any other temperature renders the correction for such temperature. These differences should be found for the various temperatures from the freezing point upward to say 100° F., and then plotted, as shown in *Fig. 3;* from the curve thus obtained a table of corrections is easily deduced.

The correction for graduation has been assumed in equation (2) to stand in direct proportion to the difference 30.—Reading, an assumption, which although not strictly correct is sufficiently so for most practical purposes.

Each Goldschmid aneroid being furnished with a table of corrections for graduations, as well as for temperature, the owner of one of these instruments is saved the trouble of investigations in this respect.

For Naudet aneroids these tables have to be obtained by the purchaser, through direct comparison of the aneroid with the mercurial barometer, the readings of both being reduced to the freezing point by means of the previously

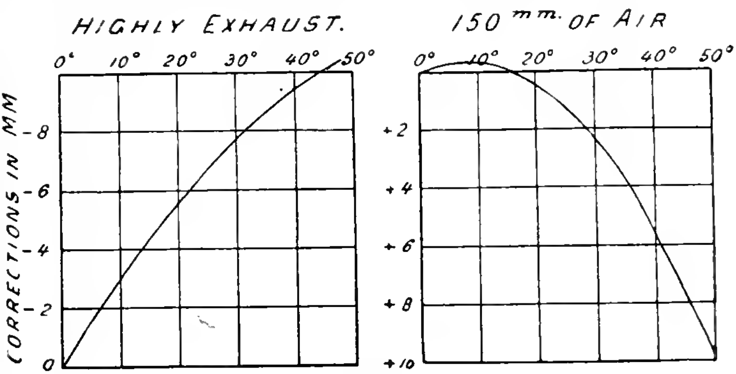


FIG. 3

determined correction for temperature. The observations are recorded in tabulated form as follows:

B_0	A	t	A_0	A_0-B_0
29·970	29·960	72	30·000	0·030
29·420	29·450	76	29·500	0·080
28·870	28·940	78	29·000	0·130

wherein the various letters have the same meaning as in equations (1) and (2). From the table it is seen that in this case the constant correction for position was

$$C = -0{\cdot}03$$

and that 1·000 inch of the aneroid correspond to 1·100 inch

of the mercurial: the coefficient of graduation therefore was

$$\beta = -0{\cdot}100$$

and by means of these figures a table of corrections for graduation can easily be worked out according to equation (2).

But if it is desired to use the aneroid at great altitudes, then it would not be safe to assume the coefficient β to remain constantly the same, and the investigation should in this case be extended to lower pressures, either by making comparisons between the mercurial barometer and the aneroid at various altitudes, or by making them by means of the air-pump. If the latter method, however, is selected, then a certain correction of the results will have to be made, the nature of which is explained by Dr. C. Koppe as follows:

Suppose an aneroid and a mercurial barometer to be at the same locality and subjected to the same atmospheric pressure, and again suppose a sudden decrease of the force of gravity to take place there. What influence would such an event have on the reading of the two instruments?

Manifestly the reading of the mercurial barometer would not be affected in the least, the weight of the column of air being diminished in the same ratio as that of the mercurial column.

It would be quite different, however, with the aneroid. While the weight of the column of air has diminished, the elastic force of the vacuum chamber has remained the same; the instrument will therefore record a lower pressure.

Consequently, if a journey is undertaken with an aneroid and a mercurial barometer, which read precisely alike, then the coincidence between both will only last as long as the force of gravity remains unchanged. But this force is different in different latitudes, and at different altitudes, and from the latter circumstance results the necessity of a correction of such tables for graduation, that were obtained by means of the air-pump.

It is clear from the above that a reading of twenty-four inches of the mercurial barometer, taken at the level of the

sea under an air-pump, indicates a *greater* actual pressure of air than the same reading taken at an altitude of 7,000 feet above the level of the sea. Hence, a correction has to be *added* to the reading of the aneroid at 7,000 feet altitude, in order to obtain coincidence of such reading with the mercurial barometer. The amount of this correction has been computed by Professor Weilenmann as follows:

Reading (inches), .	31·5	28·0	24·0	20·0	16·0
Correction, ...	0	+0·105	+0·189	+0·270	+0·312

The arithmetical sums of these figures and the corresponding corrections found by means of the air-pump are the final corrections for graduation.

The difficulty caused by "elastic reaction," which was mentioned in the beginning of this article is, of course, present also in the Goldschmid aneroid, and the above investigations, as well as all measurements of altitudes, should be carried on with due regard to it. The instrument must be given time in order to fully accommodate itself to any sudden changes of pressure.

But while Kroeber found that the Naudet required days for this, he found the Goldschmid practically accommodated after one or two hours. Again, he found the extreme differences resulting from elastic reaction in the latter instrument only about one-fourth of those in the former. Both these advantages of the Goldschmid, as compared with the Naudet, are doubtless due to the extreme simplicity of the former's mechanism, and in view of them it may be safely asserted that the gradual changes of pressure, taking place during ordinary explorations of mountainous country, will not produce any appreciable errors of elastic reaction in the Goldschmid aneroid.

V. THE DETERMINATION OF DIFFERENCES OF ALTITUDE BY MEANS OF THE ANEROID BAROMETER.

The measuring of altitudes by means of the barometer, is mainly based on two suppositions, viz: Firstly, that the atmospheric strata of equal pressure are horizontal, and secondly, that the temperature of a vertical column of air is

equal to the arithmetical mean of the temperature observed at its top and at its bottom.

These two conditions are probably *never* fulfilled completely in nature, but they are *always* fulfilled more or less approximately. On the greater or smaller deviation from them of the actually existing conditions, depends the exactitude of the result in each case, leaving out the consideration, of course, of avoidable errors of observations.

In accordance with the two principles mentioned, the process of barometric measurement may be described thus: By means of the barometer, be it a mercurial or be it an aneroid, the *weight* of a column of air is determined, and from the *observed temperature* of such column its length is found.

During observations for altitude, therefore, the temperature of the *air* as well as that of the *instrument* must be observed; the first one for the purpose named just now, the last one for the purpose of taking into proper account the corrections for temperature, by reducing both observations to uniform temperature. Besides this, the observations made at the upper and at the lower stations must of course be corrected to graduation, so that thus their difference is made equal as nearly as possible to the difference that would have been obtained by using a mercurial barometer.

It is clear at once that the observations at the upper and lower stations should be made simultaneously in order to obtain both as nearly as possible under the same atmospheric conditions. Observations made by one observer, in passing from point to point with his instrument, are quite unreliable, unless he returns to the previous point after each observation in order to take a second reading there, and thus to find the changes that have taken place in pressure and temperature. Only by means of this tedious and time-robbing procedure, can anything like fair results be obtained by one observer.

For serious work then, two observers, and at least two instruments are required, and the readings of the latter, as well as the outer and inner temperature, should be recorded with great exactitude, so as to be enabled to subsequently

introduce the proper corrections, without which the results are worthless. Great care also should be taken not to expose the aneroid to the direct rays of the sun when taking an observation, but to let it assume as nearly as possible the temperature of the surrounding air in the shadow.

The *modus operandi* in determining differences of altitude may be described about as follows:

A stationary instrument, with an observer, is placed at some point of known altitude that has been selected as the basis of operations. This instrument is observed regularly every fifteen or thirty minutes, and a careful record kept of such readings, as well as of the time and temperature corresponding to each.

Meanwhile, the engineer travels through the district he intends to survey, taking observations wherever he sees fit, and keeping a careful record of their location, time, temperature, etc. When he is through with his work, an observation at the point of known altitude is computed for each of his observations, from the record kept by the assistant; this having been done, the difference of altitude between each point of observation and the point of known altitude is obtained in a simple way, by means of the subjoined table No. 1, which has been taken from *Meteorological and Physical Tables of the Smithsonian Institution.* [Other convenient tables are given in *The Aneroid Barometer*, Van Nostrand, New York, 1888, and in the above mentioned publication of the Smithsonian Institution.]

For instance, suppose 29·5 to have been the reading at the point of known altitude, and 26·5 the reading taken by the engineer, both corrected to graduation, etc., and reduced to 32° F., and again, suppose 70° and 60° to have been the respective temperatures of the surrounding air, then we obtain from the table:

For 29·5 inches and 70° F., ...	96·5
For 26·5 inches and 60° F., ...	105·3
Mean, ...	100·9

This mean, multiplied by the difference of the two read-

ings expressed in tenths of an inch, renders the difference in altitude:

$$30 \times 100{\cdot}9 = 3{,}027 \text{ ft.}$$

The use of this table gives results of sufficient accuracy for all practical purposes, so that recourse to the complicated barometrical formula is not required.

Readings should always be taken in the same position of instrument, preferably the horizontal one.

TABLE NO. 1.

HEIGHT IN FEET OF A COLUMN OF AIR CORRESPONDING TO ONE-TENTH OF AN INCH IN THE BAROMETER.

Barometer Reading in Inches.	Temperature of Air in Degrees Fahrenheit.					
	40°	50°	60°	70°	80°	90°
23·0	116·2	118·8	121·3	123·8	126·4	129·9
23·5	113·7	116·2	118·7	121·2	123·7	126·1
24·0	111·3	113·8	116·2	118·6	121·1	123·5
24·5	109·1	111·5	113·8	116·2	118·6	121·0
25·0	106·9	109·3	111·6	113·9	116·3	118·6
25·5	104·8	107·1	109·3	111·6	113·9	116·2
26·0	102·7	105·0	107·2	109·5	111·7	114·0
26·5	100·9	103·[illegible]	105·3	107·5	109·7	111·8
27·0	99·0	101·2	103·3	105·5	107·6	109·8
27·5	97·2	99·3	101·4	103·5	105·6	107·8
28·0	95·4	97·5	99·6	101·7	103·8	105·9
28·5	93·8	95·8	97·9	99·9	101·9	103·9
29·0	92·1	94·1	96·2	98·2	100·2	102·2
29·5	90·6	92·6	94·5	96·5	98·5	100·4
30·0	89·1	91·0	92·9	94·9	96·8	98·8
30·5	87·6	89·5	91·4	93·3	95·2	97·2

TABLE NO. 2.

REDUCTION OF MERCURIAL COLUMN TO 32° F., BRASS SCALE TO BAROMETERS CORRECT AT 62° F

Temperature.	Reading of Barometer.		
	30 inches.	25 inches	20 inches.
32°	·009	·008	·006
35°	·017	·015	·012
40°	·031	·026	·021
45°	·044	·037	·030
50°	·058	·048	·038
55°	·071	·059	·047
60°	·084	·070	·056
65°	·098	·082	·065
70°	·111	·093	·074
75°	·125	·104	·083
80°	·138	·115	·092
85°	·151	·126	·101
90°	·164	·137	·110
95°	·178	·148	·118
100°	·191	·159	·127

The corrections contained in this table have to be *subtracted* from the reading of the mercurial barometer, in order to reduce the same to a temperature of 32° F.

CAPTAIN ABNEY ON HELIOCHROMY.

By F. E. Ives.

Captain Abney, in a recent address before a section of the British Association*, made some brief remarks upon the subject of heliochromy, which are, in my opinion, so misleading as to call for correction. I quote as follows:

"The nearest approach to success in producing colored pictures by light alone is the method of taking three negatives of the same subject through different colored glasses, complementary to the three color-sensations, which together give to the eye the sensation of white light. The method is open to objection on account of the impure color of the glasses used. If a device could be adopted whereby only those three parts of the spectrum could be severally used which form the color-sensations, the method would be more perfect than it is at present. Even then, perfection could not be attained, owing to a defect which is inherent in photography. This defect is the imperfect representation of gradation in tone."

According to those recent text-books on color which I have seen, only such light rays as are supposed to affect only one kind of nerve fibrils in the eye, or to excite only one of the fundamental color-sensations, can be said to form or represent primary color-sensations, and such rays are confined to both ends and a narrow strip in the middle of the visible spectrum.† If Captain Abney means to assert that in a process of this character only those rays of the spectrum should act, which represent primary color-sensations, he is certainly mistaken, and grievously misleading all those who accept him as an authority upon this subject.

---

* Reprinted in the *Scientific American Supplement*, Oct. 5, 1889, p. 11,472.

†"Helmholtz, Maxwell and Rood, as well as many other physicists, have developed the theory of Wunsch and Young, and have adopted the same, or very nearly the same, trial of primary color-sensations. These fundamental hues or primaries * * represent three widely separated and very bright colors of the spectrum."—*Color*, by A. H. Church, M. A. London, 1887. p. 67. See also Rood's *Modern Chromatics*, pp. 120–23.

It is certain that every ray of the visible spectrum should act, and act nearly in proportion to its power to excite the sensation of light in the eye. It would be ridiculous to expect that a process which reproduced the spectrum as three detached and widely separated patches of color would correctly reproduce the infinite variety of compound colors in nature, some of which are made up chiefly, and most of them partly, of rays lying in other parts of the spectrum. There are some moderately bright colors which would reproduce like black by such a process.

But it is not easy for me to believe that Captain Abney means what I have inferred from his statement, although the expressions "parts of the spectrum" and "impure color of the glasses" certainly support this inference. When he says, "those parts of the spectrum * * which form the color-sensations," it is possible that he may mean the light rays in proportion as they affect the different kinds of nerve fibrils or excite the different primary color-sensations in the eye. If so, he does not mean to divide the spectrum into three distinct parts, but aimed to state a fact which was first observed by me, and plainly set forth in my book, *A New Principle in Heliochromy*, where I showed that each heliochromic negative must be made by the joint action, in due proportion, of all rays which affect the primary color-sensation which it represents. It does not require screens of "pure color" to do this—quite the contrary. Screens of "pure color" are screens transparent to single regions of the spectrum only, and would not transmit all the rays that affect a single kind of nerve fibrils in the eye. The red, orange, yellow and yellow-green rays all affect the nerve fibrils which produce the red color-sensation, and all of them must therefore be transmitted more or less freely by the color screen used in making the negative representing that primary color-sensation. But the orange-yellow and yellow must also be transmitted to some extent by the screen used in making the negative representing the green color-sensation.

The screens must, in short, be so graduated in color as to secure, in negatives of the spectrum, curves of intensity like

the curves of a diagram representing the action of the spectrum upon the three kinds of nerve fibrils in the eye, or upon the three fundamental color-sensations; and it is a fact that such screens had been produced and that correct heliochromic negatives had been made in considerable number, and with ease and certainty, before the beginning of this year.

The observation that the inability of photography to exactly represent gradations in tone would affect the accuracy of such a method of reproducing colors, of which Capt. Abney now makes so much, originated with myself; but I also showed that by my method of proving the color screens by reference to the curves of intensity in the spectrum negatives, the effect of this defect in the negative process could be so far compensated for that it would no longer seriously affect the result, if suitable sensitive plates were employed. To say that this method does not solve the problem because of this defect, would be equivalent to saying that photography has not solved the problem of reproducing light and shade.

A NEW GRAPHICAL METHOD OF OBTAINING PIER MOMENTS.

BY C. H. LINDENBERGER.

A method of calculating strains graphically approaches perfection in just so far as it substitutes the mechanical labor of the draughtsman for the intellectual labor of the analyst. In the case of the continuous girder, there is no method that I have heard of (except the method about to be developed) of obtaining the pier moments without a great amount of analytical labor with its constant danger of gross errors and mistakes that seriously detract from its merits as a practical method of obtaining strains. This is unfortunate, for it is often necessary to know the value of the strain on a structure whose cost is measured by hundreds instead of millions of dollars, but all previous methods require an amount of labor that is practically prohibitory.

With these preliminary remarks I shall proceed to develop a purely graphic method of obtaining the pier moments of a continuous girder, that is free from almost all the objections to previous methods, being short and simple in its practical application.

Let us first begin by a few definitions.

Let the girder have s spans, and, therefore, $s + 1$ supports.

Let l_n be the length of the n[th] span from the left.

Let M_n be the moment at the n[th] support.

Let $E I'$ be the product of the constant modulus of elasticity by the constant moment of inertia.

Let P_n be a weight in the n[th] span.

Let a be its distance from the nearest left support.

Let C_n and d_n be indeterminate multipliers by the use of which the pier moments are obtained.

Let Z_s be a constant in terms of these multipliers.

Let Y_n be a term dependent on the loading and heights of the supports.

Then in a previous article in December, 1888, of this JOURNAL, I demonstrated the following theorem:

$$M_n = \frac{\left\{ \begin{array}{c} d_n (C_2 Y_2 + C_3 Y_3 + etc. + C_n Y_n) + \\ + C_n (d_{n+1} Y_{n+1} + d_{n+2} Y_{n+2} + etc. + d_s Y_s) \end{array} \right\}}{Z_s} \tag{1}$$

The equations from which the value of the indeterminate multipliers are found have the general form

$$C_{n-1}\, l_{n-1} + 2\, C_n\, (l_{n-1} + l_n) + C_{n+1}\, l_n = 0 \tag{2}$$

$$d_{n-1}\, l_{n-1} + 2\, d_n\, (l_{n-1} + l_n) + d_{n+1}\, l_n = 0 \tag{3}$$

The assumption being made that $C_1 = 0$, $C_2 = 1$, $d_{s+1} = 0$, $d_s = 1$.

The theorem of three moments is:

$$M_{n-1}\, l_{n-1} + 2\, M_n\, (l_{n-1} + l_n) + M_{n+1}\, l_n = Y_n \tag{4}$$

The value of Z_s is to be found from either of the three following equations:

$$C_{s-1}\, l_{s-1} + 2\, C_s\, (l_{s-1} + l_s) = Z_s \tag{5}$$

$$2\, d_2\, (l_1 + l_2) + d_3 l_2 = Z_s \tag{6}$$

$$(C_n\, d_{n+1} - C_{n+1}\, d_n)\, l_n = Z_s \tag{7}$$

All these formulas were demonstrated the previous

article, December, 1888. Equations (1) and (7) are the basis upon which the graphical method is developed.

There are in each of the spans two fixed points, the definitions of which are given by

$$i_n = \frac{C_n \, l_n}{C_n - C_{n+1}} \tag{8}$$

$$I_n = \frac{d_n \, l_n}{d_n - d_{n+1}} \tag{9}$$

These formulas are given by Professor Merriman in his "Theory and Calculation of Continuous Girders," Van Nostrand' *Science Series*, No. 25, the discrepancy in equation (9) being accounted for by the fact that I have numbered these d multipliers the other way.

Professor Dubois in his *Graphical Statics* gives the graphic method of finding these fixed points, but as the method is so practically important I repeat it and give the demonstration so that it may be thoroughly understood.

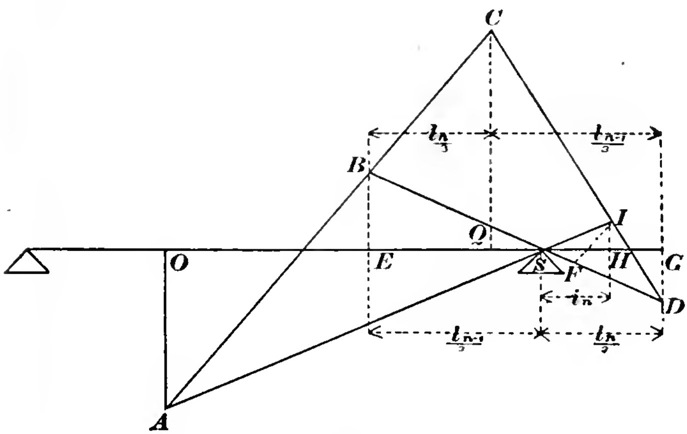


FIG. 1.

In *Fig. 1*, let s be the n[th] support and let $\overline{IF}$ be parallel to $\overline{AC}$, $\overline{OG}$ being the line of supports when on a level. Then from the two similar triangles $\overline{IFD}$ and $\overline{CBD}$ we obtain

$$\overline{IF} = \frac{\overline{CB} \times \overline{ID}}{\overline{CD}}$$

also from the similar triangles $\overline{IFS}$ and $\overline{ABS}$ obtain

$$\overline{IF} = \frac{\overline{AB}\ \overline{SI}}{\overline{SA}}$$

the relations also exist

$$\frac{\overline{SI}}{\overline{SA}} = \frac{\overline{SH}}{\overline{OS}}$$

$$\frac{\overline{ID}}{\overline{CD}} = \frac{\overline{HG}}{\overline{QG}}$$

$$\frac{\overline{CB}}{\overline{AB}} = \frac{\overline{EQ}}{\overline{OE}}$$

and placing the two values of $\overline{IF}$ equal we obtain

$$\frac{\overline{EQ} \times \overline{HG}}{\overline{OE} \times \overline{QG}} = \frac{\overline{SH}}{\overline{OS}}$$

Let $\overline{ES} = \frac{l_{n-1}}{3}$ $\overline{SG} = \overline{EQ} = \frac{l_n}{3}$, $SH = i_n\, O\,S = L_{n-1}$

whence

$$\overline{OE} = L_{n-1} - \frac{l_{n-1}}{3},\quad \overline{HG} = \frac{l_n}{3} - i_n,\quad \overline{QG} = \overline{SE} = \frac{l_{n-1}}{3}$$

Substitute these values, transpose and we get after reduction

$$i_n = \frac{L_{n-1}\, l_n}{l_{n-1}\left(\frac{3\,L_{n-1}}{l_{n-1}}\left(\frac{l_n + l_{n-1}}{l_n}\right) - \frac{l_{n-1}}{l_n}\right)}$$

and from equation (2) we obtain

$$\frac{l_{n-1}}{l_n} = -\,\frac{C_{n+1} + 2\,C_n}{C_{n-1} + 2\,C_n}$$

$$\frac{l_n + l_{n-1}}{l_n} = \frac{C_{n-1} - C_{n+1}}{C_{n-1} + 2\,C_n}$$

giving by substitution

$$i_n = + \frac{L_{n-1}\, l_n\, (C_{n-1} + 2\, C_n)}{l_{n-1}\left(\frac{3\, L_{n-1}}{l_{n-1}}\left(C_{n-1} - C_{n+1}\right) + (C_{n+1} + 2\, C_n)\right)}$$

To give a definite value to i_n we must assume a value for L_{n-1}, therefore assume

$$L_{n-1} = - \frac{l_{n-1}\quad C_n}{C_{n-1} - C_n}$$

and this gives after substituting and reducing

$$i_n = \frac{C_n\, l_n}{C_n - C_{n+1}}$$

as it should, and therefore

$$L_{n-1} = l_{n-1} - i_{n-1}.$$

In like manner the construction and demonstration may be made for the fixed points $I_1\, I_2$, etc., in the same manner, except that we commence at the right instead of the left. The construction is simple and is evident from the demonstration, which was given more to illustrate that than anything else.

The next thing is a formula for the moments at the supports in terms of these fixed points. Referring to equation (1), we will have $Y_n = A_n + B_{n-1}$, $Y_{n+1} = A_{n+1} + B_n$; it being first supposed that the supports are all on a level and

$$A_n = \Sigma\, P_n\, l_n^2\, (2\, k - 3\, k^2 + k^3)$$

$$B_n = \Sigma\, P_n\, l_n^2\, (k - k^3), \text{ and } k = \frac{a}{l_n}.$$

Here it would be proper to give a diagram for the determination of

$$\frac{A_n}{l_n^2} \text{ and } \frac{B_n}{l_n^2},$$

which is accordingly done in *Fig. 2*, where $\overline{O\, L}$ is taken to represent the span, and $\overline{O\, P} = P$ to a sufficiently large

scale, and the lines $\overline{G\ C}$, $\overline{H\ K}$, $\overline{D\ J}$ and $\overline{P\ I}$ are parallel to $\overline{O\ L}$ and perpendicular to $\overline{O\ P}$.

Let $\overline{O\ A} = \overline{P\ B} = a = k\ l$, then $\overline{A\ L} = (1 - k)\ l$, and $\overline{A\ F} = P\ (1 - k) = \overline{L\ K} = \overline{O\ H}$. $\overline{C\ F} = P\ (1 - k)^2 = \overline{G\ H}$ and $\overline{M\ F} = P\ (1 - k)^3$; and therefore

$$\begin{aligned} \overline{A\ M} &= \overline{A\ F} - \overline{M\ F} = P\ (1 - k - (1 - k)^3) \\ &= P\ (2\ k - 3\ k^2 + k^3) \end{aligned}$$

$\overline{F\ B} = P\ k = \overline{H\ P} = \overline{K\ I}$ and $\overline{D\ F} = P\ k^2 = \overline{K\ J}$ and

$\overline{F\ E} = P\ k^3$, and therefore

$\overline{E\ B} = P\ (k - k^3)$.

Referring again to equation (1) and inserting the value of Z_s given by equation (7), let us suppose that only the n[th] span is loaded.

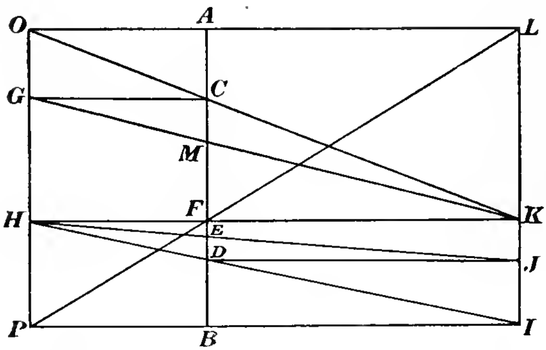


FIG. 2.

Then we have

$$M_n = \frac{d_n\ C_n\ A_n + C_n\ d_{n+1}\ B_n}{(C_n\ d_{n+1} - C_{n+1}\ d_n)\ l_n}$$

Substituting the values of i_n and I_n from equations (8) and (9), we obtain

$$M_n = \frac{I_n\ i_n \frac{A_n}{l_n^2} - i_n\ (l_n - I_n)\ \frac{B_n}{l_n^2}}{I_n - i_n} \tag{10}$$

Referring again eq. 1, we write

$$M_{n+1} = \frac{\left\{ \begin{array}{c} d_{n+1}\ (C_2\ Y_2 + C_3\ Y_3 + etc. + C_n\ Y_n + C_{n+1}\ Y_{n+1}) \\ + C_{n+1}\ (d_{n+2}\ Y_{n+2}, etc., etc., + d_s\ Y_s) \end{array} \right\}}{Z_s}$$

Supposing, as before, that only the n[th] span is loaded, we have

$$M_{n+1} = \frac{d_{n+1}\, C_n\, A_n + C_{n+1}\, d_{n+1}\, B_n}{(C_n\, d_{n+1} - C_{n+1}\, d_n)\, l_n}$$

and substituting the value of i_n and I_n as before, we get

$$M_{n+1} = \frac{(l_n - I_n)\,(l_n - i_n)\,\frac{B_n}{l_n^2} - i_n\,(l_n - I_n)\,\frac{A_n}{l_n^2}}{I_n - i_n} \qquad (11)$$

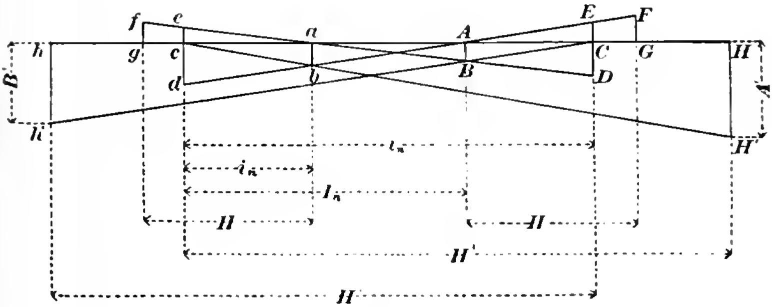


FIG. 3.

Subtracting this equation from equation (10) and dividing the result by l_n, gives

$$\frac{M_n - M_{n+1}}{l_n} = \frac{i_n\,\frac{A_n}{l_n^2} - (l_n - I_n)\,\frac{B_n}{l_n^2}}{I_n - i_n} \qquad (12)$$

Since

$$\frac{A_n}{l_n^2} \text{ and } \frac{B_n}{l_n^2}$$

we have seen may each be represented by a line, let

$$\frac{A_n}{l_n^2} = A_n' \text{ and } \frac{B_n}{l_n^2} = B_n'$$

$$\frac{M_n}{H} \text{ and } \frac{M_{n+1}}{H}$$

will also be represented by *A* line if *H* is a line representing a force, and will usually be taken equal to the pole distance of the force polygon.

When there are several weights on the span, it will be found in practice that *P* must be taken in *Fig. 2* to a con-

siderably larger scale than is convenient for the force polygon or shear line, because in this way cumulative errors are avoided to some extent.

In *Fig. 3* let $\overline{Cc}$ be the length of the n[th] span and let $\overline{ca} = i_n$, $\overline{cA} = I_n$, $\overline{hC} = \overline{cH} = H'$, where H' is the length of a line representing H to the same scale that P is taken in *Fig. 2*. Lay off in the figure $\overline{HH'} = A_n'$ $\overline{hh'} = B_n'$ taken from *Fig. 2*, then

$$\overline{AB} = \frac{B_n'}{H'}(l_n - I_n)$$

$$\overline{CD} = \frac{A\,B\,(l_n - i_n)}{I_n - i_n} = \frac{B_n'}{H'}\,\frac{(l_n - i_n)(l_n - I_n)}{I_n - i_n} =$$

$$= \frac{(l_n - i_n)(l_n - I_n)}{I_n - i_n}\,\frac{P(k - k^3)}{H}$$

$$\overline{ec} = A\,B\,\frac{i_n}{I_n - i_n} = \frac{B_n'}{H'}\,\frac{i_n(l_n - I_n)}{I_n - i_n} =$$

$$= \frac{i_n(l_n - I_n)}{I_n - i_n}\,\frac{P(k - k^3)}{H}$$

$$\overline{ab} = \frac{A_n}{H'}\,i_n,\ cd = a\,b\,\frac{I_n}{I_n - i_n} = \frac{A_n'}{H'}\,\frac{I_n\,i_n}{I_n - i_n} =$$

$$= \frac{I_n\,i_n}{I_n - i_n}\,\frac{P(2k - 3k^2 + k^3)}{H}$$

$$\overline{EC} = \frac{\overline{ab}\,(l_n - I_n)}{I_n - i_n} = \frac{A_n}{H'}\,\frac{i_n(l_n - I_n)}{I_n - i_n} =$$

$$= \frac{i_n(l_n - I_n)}{I_n - i_n}\,\frac{P(2k - 3k^2 + k^3)}{H}$$

and from the foregoing

$$\frac{M_n}{H} = \overline{cd} - \overline{ec}$$

$$\frac{M_{n+1}}{H} = \overline{CD} - \overline{EC}$$

Let $\overline{ag} = \boldsymbol{A}\,G = H$ to the scale of the pole distance in the force polygon.

Then

$$\overline{fg} = \frac{\overline{EC} \times H}{i_n} = \frac{P(k - k^3)(l_n - I_n)}{I_n - i_n}$$

also

$$\overline{FG} = \frac{\overline{cc} \times H}{(l_n - I_n)} = P(2k - 3k^2 + k^3)\frac{i_n}{I_n - i_n}$$

and therefore

$$\frac{M_n - M_{n+1}}{l_n} = \overline{FG} - \overline{fg}$$

to the same scale as H.

This is an important quantity, as it is needed in the shear line, since the equations for the shear are

$$S_n = \frac{M_n - M_{n+1}}{l_n} + \Sigma P(1 - k)$$

$$S_n' = \frac{M_n - M_{n+1}}{l_n} - \Sigma P k = S_n - \Sigma P$$

Where S_n is the shear just to the right of the n^th^ support.

Having now found the moments at the n^th^ and (n + 1)^th^ support due to a load in the n^th^ span the moments due to this load at any other support are easily found and the method is given by other writers but is nevertheless repeated here.

Let M_q be the moment desired, there being no load except on the n^th^ span and the supports on a level

Then from Eq. (*1*) where $n > q$ we have

$$M_q = \frac{C_q}{C_n} M_n$$

or what is the same thing

$$M_q = \left(\frac{C_q}{C_{q+1}} \times \frac{C_{q+1}}{C_{q+2}} \cdot etc. \times \frac{C_{n-2}}{C_{n-1}} \times \frac{C_{n-1}}{C_n} \right) M_n$$

and from equation (8) this becomes

$$M_q = \left(\frac{i_q}{i_q - l_q} \times \frac{i_{q+1}}{i_{q+1} - l_{q+1}} \cdot etc. \times \frac{i_{n-2}}{i_{n-2} - l_n} \right.$$
$$\left. \times \frac{i_{n-1}}{i_{n-1} - l_{n-1}} \right) M_n$$

In like manner from equation (1) where $(n + 1) < q$ we obtain

$$M_q = \frac{d_q}{d_{n+1}} M_{n+1}$$

or the identical equation

$$M_q = \left(\frac{d_q}{d_{q-1}} \times \frac{d_{q-1}}{d_{q-2}} \times etc. \times \frac{d_{n+3}}{d_{n+2}} \times \frac{d_{n+2}}{d_{n+1}}\right) M_{n+1}$$

and from equation (9)

$$M_q = \left(\frac{I_{q-1} - l_{q-1}}{I_{q-1}} \times \frac{I_{q-2} - l_{q-2}}{I_{q-2}} \times etc. \times \frac{I_{n+2} - l_{n+2}}{I_{n+2}} \times \right.$$
$$\left. \times \frac{I_{n+1} - l_{n+1}}{I_{n+1}}\right) M_{n+1}$$

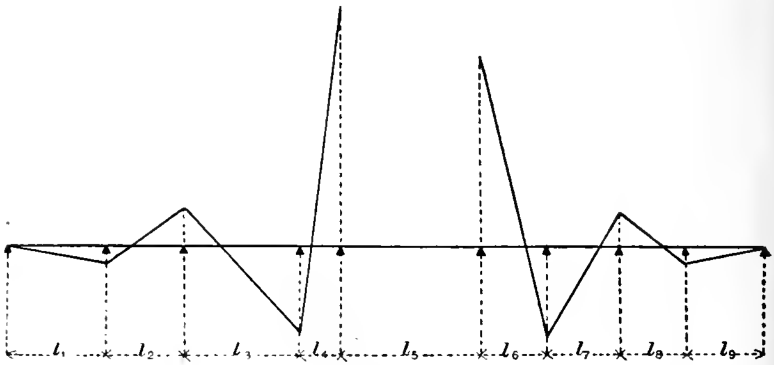


FIG. 4.

The graphical method of interpreting these equations is shown in *Fig. 4*, in which there are nine spans, but the fifth span only is loaded. At the fifth support the ordinate $= \frac{M_5}{H}$ and a line through its extremity and through the fixed point nearest the fourth support cuts off from the vertical through the fourth support a line $= \frac{M_4}{H}$, the operation is repeated for the next and so on, and a similar operation takes place on the right. If the supports are counted each way from the loaded span, the moments at the odd supports will be negative, and those at the even supports will be positive, a positive moment being one that causes tension on the upper chord or flange.

It will be observed that Eq. (8) gives $i_1 = o$, hence $L_1 = l_1$. Also from Eq. (9) $I_s = l_s$.

The construction for I_1, I_2, etc., etc., is easily found by remembering that these fixed points would not change their actual position if the order of the spans was reversed. Hence, the graphical construction is the same as for i_2, i_3, etc., etc., except that we begin at the right and work towards the left, instead of the opposite, as shown in *Fig. 1*. The obliquity of the line $\overline{A\ C}$ and the length of the line $\overline{A\ O}$ is arbitrary.

The next problem to attack is the moment due to the sinking of any one of the supports which can also be shown to be more easily solved graphically than analytically. In this case it is to be remembered that the girder is to be wholly unloaded, and these moments are just sufficient to compel contact with the supports.

For this case the well-known formula is—

$$Y_n = -6\ E\ I' \left\{ \frac{h_n - h_{n+1}}{l_n} + \frac{h_n - h_{n-1}}{l_{n-1}} \right\}$$

Let all the supports be on a level, except the n[th] support and this support be depressed *below* the level of the rest by the distance h.

Now, recollecting that this makes—

$$Y_{n-1} = 6\ E\ I' \frac{h}{l_{n-1}}$$

$$Y_n = -\frac{6\ E\ I'\ h}{l_n\ l_{n-1}} (l_{n-1} + l_n)$$

$$Y_{n+1} = 6\ E\ I' \frac{h}{l_n}$$

and that all the other $Y^s = o$, we can easily derive the following formulas, M_q being the moment sought:

for $q < n$

$$M_q = \frac{6\ E\ I'\ h}{Z_s} C_q \left\{ \frac{d_{n-1} - d_n}{l_{n-1}} + \frac{d_{n+1} - d_n}{l_n} \right\} \qquad (13)$$

for $q = n$

$$M_q = M_n = \frac{6\,E\,I'\,h}{Z_s}\left\{\frac{d_n\,(C_{n-1} - C_n)}{l_{n-1}} + \frac{C_n\,(d_{n+1} - d_n)}{l_n}\right\} \quad (14)$$

for $q > n$

$$M_q = \frac{6\,E\,I'\,h}{Z_s}\,d_q\left\{\frac{C_{n-1} - C_n}{l_{n-1}} + \frac{C_{n+1} - C_n}{l_n}\right\} \quad (15)$$

In Eq. (13) make $q = n - 1$; and in Eq. (15) make it $= n + 1$; and take $Z_s = (C_n\,d_{n+1} - C_{n+1}\,d_n)\,l_n$; and substitute from Eqs. (8) and (9) and we obtain the following equations:

$$M_{n-1} = \frac{6\,E\,I'\,h}{l_n^2}\left\{\frac{i_{n-1}\,i_n\,(I_n + l_{n-1} - I_{n-1})}{(l_{n-1} - i_{n-1})\,(l_{n-1} - I_{n-1})\,(I_n - i_n)}\right\} \quad (16)$$

$$M_n = -\frac{6\,E\,I'\,h}{l_n^2}\left\{\frac{i_n\,(I_n + l_{n-1} - i_{n-1})}{(l_{n-1} - i_{n-1})\,(I_n - i_n)}\right\} \quad (17)$$

$$M_{n+1} = \frac{6\,E\,I'\,h}{l_n^2}\left\{\frac{(i_n + l_{n-1} - i_{n-1})\,(l_n - I_n)}{(l_{n-1} - i_{n-1})\,(I_n - i_n)}\right\} \quad (18)$$

By making $Z_s = (C_{n-1}\,d_n - C_n\,d_{n-1})\,l_{n-1}$; which is merely reducing the subscripts in Eq. (7) by unity we get by substituting the values of the fixed points:

$$M_{n-1} = \frac{6\,E\,I'\,h}{l_{n-1}^2}\left\{\frac{(I_n + l_{n-1} - I_{n-1})\,i_{n-1}}{(I_{n-1} - i_{n-1})\,I_n}\right\} \quad (19$$

The only practical value of these formulas is to obtain a diagram for the graphical calculation of moments at the supports which I will now proceed to explain.

In *Fig. 5*, let *A* be the $(n - 1)^{th}$ support, *D* the n^{th} support and *G* the $(n + 1)^{th}$ support. *B* and *C* are the fixed points in the span l_{n-1} and *E* and *F* those in the span l_n.

Let *H* be any arbitrarily assumed force, then lay off in a vertical through *D* a line $=$

$$\frac{6\,E\,I'\,h}{H\,l_n^2} = \overline{D\,p} = p$$

say, and through its extremity draw $\overline{B\,f}$ and drop vertical $\overline{c\,C}$, $e\,E$ and $\overline{F\,f}$, then

$$F\,f = p\,\frac{(I_n + l_{n-1} - i_{n-1})}{l_{n-1} - i_{n-}}$$

produce the vertical $\overline{Dp}$ below the line of supports, and draw $\overline{fd}$ through E, cutting this vertical at d, then

$$\overline{Dd} = \frac{\overline{Ff}\, i_n}{I_n - i_n} = p\,\frac{(I_n + l_{n-1} - i_{n-1})\, i_n}{(l_{n-1} - i_{n-1})(I_n - i_n)} = -\frac{M_n}{H}$$

We also have

$$\overline{Ec} = p\,\frac{(i_n + l_{n-1} - i_{n-1})}{l_{n-1} - i_{n-1}}$$

Draw $\overline{cg}$ through F, cutting the vertical through G at g, then

$$\overline{Gg} = \frac{\overline{Ec}\,(l_n - I_n)}{I_n - i_n} = \frac{p\,(i_n + l_{n-1} - i_{n-1})(l_n - I_n)}{(l_{n-1} - i_{n-1})(I_n - i_n)} = \frac{M_{n+1}}{H}$$

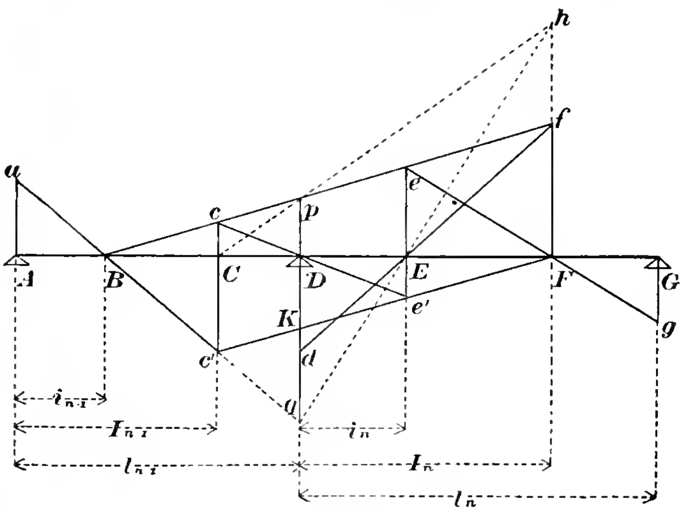


FIG. 5.

Through p draw $\overline{Ch}$, cutting the vertical $\overline{Ff}$ produced at h, then

$$\overline{Fh} = p\,\frac{(I_n + l_{n-1} - I_{n-1})}{l_{n-1} - I_{n-1}}$$

Through E draw $\overline{hq}$, cutting $\overline{Dd}$ produced at q, then

$$\overline{Dq} = \overline{Fh}\,\frac{i_n}{I_n - i_n} = p\,\frac{(I_n + l_{n-1} - I_{n-1})\, i_n}{(l_{n-1} - I_{n-1})(I_n - i_n)}$$

Through B draw $\overline{a\,q}$, cutting the vertical through A at a, then

$$\overline{A\,a} = D\,q\,\frac{i_{n-1}}{(l_{n-1} - i_{n-1})} =$$

$$= p\,\frac{(I_n + l_{n-1} - I_{n-1})\,i_n\,i_{n-1}}{(l_{n-1} - I_{n-1})\,(I_n - i_n)\,(l_{n-1} - i_{n-1})} =$$

$$= \frac{M_{n-1}}{H}$$

It will often happen that when $\overline{C\,D}$ is small that the line $\overline{F\,h}$ is so long that this construction is impracticable and inaccurate. Hence, a different method must be devised. We have

$$\overline{C\,c} = p\,\frac{(I_{n-1} - i_{n-1})}{(l_{n-1} - i_{n-1})}$$

Produce $C\,c$ to intersection with the $\overline{a\,q}$ at c', then

$$\overline{C\,c'} = \overline{D\,q}\,\frac{(I_{n-1} - i_{n-1})}{l_{n-1} - i_{n-1}} =$$

$$= p\,\frac{(I_n + l_{n-1} - I_{n-1})\,i_n\,(I_{n-1} - i_{n-1})}{(l_{n-1} - I_{n-1})\,(I_n - i_n)(l_{n-1} - i_{n-1})}$$

The point c' is not known, however, if the construction of h is impracticable, hence, through D draw $\overline{c\;c'}$, cutting $\overline{E\,c}$ produced at c', then

$$E\,c' = \frac{C\,c'\,i_n}{l_{n-1} - I_{n-1}} = \frac{p\,(I_{n-1} - i_{n-1})\,i_n}{(l_{n-1} - i_{n-1})\,(l_{n-1} - I_{n-1})}$$

Through c' draw the line $F\,c'$ and produce it indefinitely to the left, cutting the vertical $\overline{D\,d}$ at K and the vertical $\overline{c\,C}$ produced at some point, say c'' if it be not the same as c', then we will have

$$D\,K = \frac{E\,c'\,I_n}{I_n - i_n} = p\,\frac{(I_{n-1} - i_{n-1})\,i_n\,I_n}{(l_{n-1} - i_{n-1})\,(l_{n-1} - I_{n-1})\,(I_n - i_n)}$$

$$C\,c' = C\,c'' = \frac{\overline{E\,c'}\,(I_n + l_{n-1} - l_{n-1})}{I_n - i_n} =$$

$$= \frac{p\,(I_{n-1} - i_{n-1})\,i_n\,(I_n + l_{n-1} - I_{n-1})}{(l_{n-1} - i_{n-1})\,(l_{n-1} - I_{n-1})\,(I_n - i_n)}$$

Hence, it is evident that c'' and c' are the same point. Now

$$Z_s = (C_n\, d_{n+1} - C_{n+1}\, d_n)\, l_n = (C_{n-1}\, d_n - C_n\, d_{n-1})\, l_{n-1}$$

and by inserting the values of the fixed points and reducing, we finally attain

$$\frac{l_n^2}{l_{n-1}^2} = \frac{I_n\, i_n\,(I_{n-1} - i_{n-1})}{(l_{n-1} - i_{n-1})\,(l_{n-1} - I_{n-1})\,(I_n - i_n)} \tag{20}$$

whence

$$\overline{D\,K} = \frac{p\, l_n^2}{l_{n-1}^2} = \frac{6\, E\, I'\, h}{l_{n-1}^2} \tag{21}$$

The application of Eq. (19) is now apparent, and need not be further explained. The quantity $\frac{6\, E\, I\, h}{l_n^2}$ need only be calculated for a single span, as is evident from Eq. (21).

It might here be remarked that the maximum and minimum strains on a continuous girder are much more easily discussed when the equations are put in terms of the fixed points, and the theoretical results are more easily understood, but this of itself would require a treatise on the subject, which is of itself a large one.

This completes all that is necessary, without going over ground that others have trod, and, as I have shown, all the strains can be obtained *without any analysis whatever* further than is necessary at first to thoroughly comprehend the system. In fact, *one does not even need to know the value of the indeterminate multipliers*. The results obtained are *theoretically accurate*, and their precision is limited only by the scales used and the skill and care of the draughtsman, and as for rapidity, certainly I think no fault will be found on that score, and any one that understands graphical statics sufficiently to construct an equilibrium polygon can obtain all the important strains in a very short time.

It will be observed that all the formulas and diagrams are for unequal spans. This is the most general case, and includes the cases for spans equal, ends fixed, etc., as special cases.

CONSTANT FOCUS AND DEPTH OF FOCUS IN PHOTOGRAPHIC LENSES.

By William A. Cheyney.

Since the introduction of detective cameras we have heard and read much about lenses having a fixed or constant focus for all objects at all distances from the lens, from four feet upward, and this has led to claims being made, for the lenses of different manufacturers, which have been surprising and at variance with all known laws of optics.

This condition of affairs induced me to make a series of experiments, with a number of lenses made by different manufacturers, in order to convince myself as to what extent these statements could be relied upon. The result of which I give you, as follows:

There is no such thing as a constant focus for any lens; the plane of absolute sharpness varies for every point, at which the object may be, between an infinitely distant point and the lens.

That there is a plane of absolute sharpness, in all well-corrected lenses, there can be no question, and the determination of this plane only depends upon the extent to which the image on the ground glass is magnified.

There is, however, a distance through which the ground glass may be moved, and yet the error in the sharpness of the image cannot be detected by the human eye, this distance varies inversely as the ratio of the diameter of the aperture of the lens (the diameter of the opening in the diaphragm used) to the equivalent focus of the lens (the distance from the optical centre of the lens to the ground glass, when an object infinitely distant would give an absolutely sharp image).

This grows out of the fact that the human eye cannot detect an error in sharpness, when the error is not greater than $\frac{1}{250}$ of an inch.

To illustrate this, I present *Fig. 1.*

Here we have the cone of light from a lens working with an aperture of $f/8$ represented by the lines *b d* and *b e* and the position of the plane of absolute sharpness by the line *a b c* (being the position of the ground glass). Now when the ground glass is pushed up to the position indicated by the line *f g h i* we have what would be a mathematical point at *b*, increased to a blurred spot having a diameter represented by the line *g h*, and whenever the length of this line

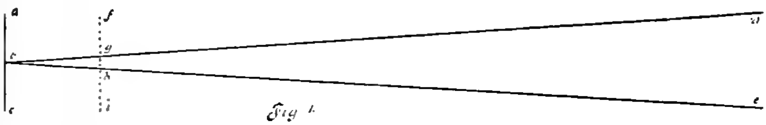


Fig. 1.

g h is $\frac{1}{250}$ of an inch or less, it will be impossible for the unaided human eye to detect the error.

But I stated before that this movement of the ground glass varies inversely as the ratio of the diameter of the aperture of the lens to the equivalent focus thereof, and in order to show this, I will call your attention to *Fig. 2*, given below.

In this figure we have the cone of light from a lens working with an aperture of $f/16$ and the conditions are the same as in the former example, excepting that, while the

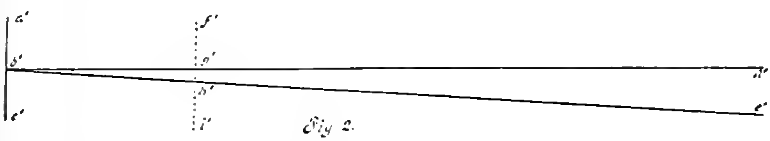


Fig. 2.

line *g′ h′* is equal to the line *g h* it will be twice as far from the point *b′* as *g h* was from the point *b*.

Now these conditions are true for a point back of the ground glass.

Here let me say, that this distance from the point in front of the ground glass to the one behind it, between which the error in sharpness is inappreciable, gives rise to what is known as depth of focus in a lens, which is here shown to vary according to the ratio between the diameter of the aperture and the equivalent focus of the

lens and which depends for its existence upon the inability of the human eye to detect the error.

This accounts for the fact that our beautiful little negative, in which we have taken advantage of all the depth of focus of our lens, when it comes to be enlarged gives an unsatisfactory picture. Why? Because we have enlarged the error of focus until the eye is able to detect it.

Still there are some of us who do not desire to make enlargements from our negatives and for the benefit of those I will go further with the results of my experiments.

I found the following rule to be true by actual experiment with lenses of nine of the most reliable manufacturers, as well as by computation:

Multiply the diameter of the aperture of a lens by the equivalent focus thereof; divide the product by the greatest imperceptible error, and to the quotient add the equivalent focus. The sum will be the distance of an object upon which a lens should be accurately focused in order that all objects beyond a point one-half of the above distance shall be apparently in focus.

Thus let f equal the equivalent focus, a equal the diameter of aperture and c equal the greatest allowable error; then d will equal the distance of an object upon which, if the lens be accurately focused, all objects beyond $d/2$ will apparently be in focus:

$$\frac{a \times f}{c} + f = d$$

Or, say we are using a lens with an equivalent focus of eight inches and the $f/8$ diaphragm, then we have

$$\frac{1 \times 8}{\frac{1}{250}} + 8 = 2{,}008 \text{ inches} = 167 \text{ feet } 4 \text{ inches.}$$

Now, if we focus upon an object 167 feet 4 inches from the lens, all objects beyond 83 feet 8 inches will be in apparent focus.

Or again, if we use a lens, the equivalent focus of which is four inches and use the $f/16$ diaphragm, we have

$$\frac{\frac{1}{4} \times 4}{\frac{1}{250}} + 4 = 254 \text{ inches} = 21 \text{ feet } 2 \text{ inches.}$$

And here, if we focus on an object 21 feet 2 inches from the lens, then all objects beyond 10 feet 7 inches will apparently be in focus.

As the result of the foregoing, I give the following table:

Equivalent Focus in Inches.	*Diaphragm.*	*Distance of Object Focused Upon.*	*All Objects in Focus Beyond.*
8	f/8	167 ft. 4 in.	83 ft. 8 in.
8	f/11·31	125 ft. 8 in.	62 ft. 10 in.
8	f/16	84 ft.	42 ft.
7	f/8	126 ft. 1¼ in.	63 ft. 0⅝ in.
7	f/11·31	94 ft. 8 $\frac{11}{16}$ in.	47 ft. 4$\frac{11}{32}$ in.
7	f/16	63 ft. 4⅛ in.	31 ft. 8$\frac{1}{16}$ in.
6	f/8	94 ft. 3 in.	47 ft. 1½ in.
6	f/11·31	70 ft. 9¾ in.	35 ft. 4⅞ in.
6	f/16	47 ft. 4½ in.	23 ft. 8¼ in.
5	f/8	65 ft. 6¼ in.	32 ft .9⅛ in.
5	f/11·31	49 ft. 3$\frac{1}{16}$ in.	24 ft. 7$\frac{17}{32}$ in.
5	f/16	32 ft. 11⅝ in.	16 ft. 5$\frac{13}{16}$ in.
4	f/8	42 ft.	21 ft.
4	f/11·31	31 ft. 3 in.	15 ft. 7½ in.
4	f/16	21 ft. 2 in.	10 ft. 7 in.
3	f/8	23 ft. 8¼ in.	11 ft. 10⅛ in.
3	f/11·31	17 ft. 10$\frac{1}{16}$ in.	8 ft. 11$\frac{1}{32}$ in.
3	f/16	11 ft. 11⅝ in.	5 ft. 11$\frac{13}{16}$ in.
2	f/8	10 ft. 7 in.	5 ft. 3½ in.
2	f/11·31	7 ft. 11¾ in.	3 ft. 11⅞ in.
2	f/16	5 ft. 4½ in.	2 ft. 8¼ in.

By an examination of the foregoing table, two facts are seen: (1) That, while the focus shortens in an arithmetical progression, the distance of the object in focus decreases geometrically, thus showing the reason that short focus lenses have a greater depth of focus than those of long focus; and (2) That the distance to the object in focus decreases directly as the diameter of the diaphragm is smaller, thus demonstrating the cause of the increase of depth of focus by the use of smaller diaphragms.

And, finally, you should know that the lenses used in these experiments were of the kinds known as rectilinear or moderate angle, wide angle and landscape, or single combination lenses.

Cheyney, Pa., October 10, 1889.

THE HAIL-STORM AT PHILADELPHIA, OCTOBER 1, 1889.

BY PROF. EDWIN J. HOUSTON.

During the hail-storm, which occurred in Philadelphia on the 1st of October, 1889, some phenomena were presented of sufficient interest to place on record. The storm occurred towards the close of the day, shortly before sunset, and was heralded by the usual banks of dark clouds and strong wind currents in the upper atmospheric regions. It began with a fall of rain, with strong wind, and was followed by a copious fall of hail-stones, varying from small granules, to spheroids of an inch to an inch and a quarter in diameter.

An examination made by the author of some hail-stones that fell on a grass-plot in the northern section of the city, showed the following characteristics, viz:

(1) A cross-section of some twenty or thirty stones showed the usual alternate concentric layers of opaque and transparent ice.

(2) The nucleus of all the hail-stones examined was of opaque ice.

(3) Many of the larger stones had a nearly spherical shape, and were only slightly oblately-spheroidal.

(4) In some of the stones, however, mainly in the smaller ones, the oblately-spheroidal form was so distinctly marked, that the form of discs or flat cylinders was closely simulated.

(5) Nearly all the stones showed an opaque outer layer.

The above points are common to most hail-stones, and are only referred to in connection with a sixth characteristic, which I have never before noticed in hail-stones, nor have I ever known the same to be mentioned in the literature of the subject.

On some of the stones, though not on the majority of them, well marked crystals of clear transparent ice projected

from their outer surfaces for distances ranging from an eighth to a quarter of an inch.

These crystals, as well as I could observe from the evanescent nature of the material, were hexagonal prisms with clearly cut terminal facets. They resembled the projecting crystals that form so common a lining in geodic masses, in which they have formed by gradual crystalization from the mother-liquor. They differed, however, of course, in being on the outer surface of the spherules.

What conditions could have existed in the dense masses of vapor from which the stones received their successive coatings, which permitted the vapor to act as a mother-liquor, despite the violent motions of the stones, so generally assumed to exist during their formation, is difficult to conceive. The formation of such crystals would seem to require comparative rest of the stones in a dense vapor a short period before their final fall to the earth. Is it probable that the crystal-encrusted hail-stones were in a condition of such comparative rest for a sufficient length of time immediately before their fall to the earth to permit the gradual deposition of the well-marked crystals observed?

I know of no theory for the formation of hail-stones, which will permit of such a condition, except the theory of an ascending current, suggested by Mr. Wm. P. Tatham, in an article entitled "A Contribution to Meteorology," which appeared in this JOURNAL (see J. F. I., June, 1889, p. 437, *et seq.*), and it is not improbable, in my opinion, that such air currents were instrumental in producing these peculiar hailstones.

Bearing in mind the low temperature required for the formation of hail, the statements of Oefers, *Akad. Forhandl.*, 1860, p. 439, that under the strong cold attending a fall of snow, ice is formed in the shape of well-formed six-sided prisms, are in accordance with the shape of the crystals observed.

I have referred to the phenomena of the crystal-studded hail-stone, not for the purpose of urging the acceptance of any particular theory for the formation of hail, nor for the purpose of offering any explanation, but for simply placing on record an observed fact.

Unfortunately, I had no camera at hand, and therefore obtained no photographic details of the crystal-studded hailstones.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, October 12, 1889.

THE SANITARY DISPOSITION OF THE DEAD.

By DR. C. A. HARVEY, New York City.

[*Being the Substance of an Address delivered at the Stated Meeting, held Wednesday, September 18, 1889.*]

It may be safe to say that there is no problem that confronts us to-day which is more fraught with vital importance, from a sanitary standpoint, than that which concerns the best method of disposing of the dead. But it is a question around which gather great and important interests, and not a few difficulties.

There are certain habits and customs of a people which indicate the measure of civilization, of refined sentiment and sense of moral obligation to which they have attained. In nothing, perhaps, do these customs, either in individuals or in a people, more strikingly appear than in the treatment and disposition of the dead. Where these qualities dominate there is manifest for the dead the most profound respect and tender care. Hence, to approach, at this advanced stage of our civilization, a discussion of the subject of "the best means of disposing of the dead" will be to direct attention to a subject for which the way is already measurably prepared. And the more so, because of the considerable attention which is now being given to this subject in nearly every part of the civilized world. The fact that this subject is receiving such attention argues a dissatisfaction among thinking men, with existing and long-practiced methods. A dissatisfaction which is plainly traceable to the light which scientific investigation has

thrown upon the serious evils attendant upon the practice of inhumation. Yet, this method has prevailed so long and is such a time-honored custom, that comparatively few persons ever give a thought to any disposition of human remains other than that of burial in the ground; and few suspect that a method vastly more in accord with the feelings of all who meditate upon the subject, far more congenial to humane sensibilities, and, at the same time, perfectly sanitary, so that the dead shall not perpetually endanger the health and lives of the living, can at once be made available and placed within the reach of all. It is, undeniably, one of the first duties of those who are interested in the public weal—the best interests of their fellows, to seek for and strive to secure to them those conditions which shall be most conducive to the best physical conditions of individuals and communities. Says Sir Spencer Wells: "A knowledge of sanitary science, of the conditions which are necessary for the health of mankind, is still confined to the comparatively few, who may be called the well-educated classes." And he adds that it is "the best educated classes who are most earnest in their efforts to disseminate the branch of knowledge or science which, in the words of Parkes, aims at rendering 'youth most perfect, decay less rapid, life more vigorous and death more remote.'"

It is a marked characteristic of this age, more than of any other, that greater attention has been given to sanitation and to the laws which are conducive to health and longevity.

It is now very widely admitted that one of the most unsanitary customs which has ever been practiced is that of placing dead human bodies in the ground, there to gradually decay and poison the air, the earth and the water, the three elements upon which the living subsist. Indeed, sanitary science has long proclaimed against the time-honored custom of committing the dead to mother earth and leaving to unaided nature the process of resolving the complex compounds constituting the human body to their simple elements; which processes of organic decay are dangerous in the highest degree to the health and lives of the living.

Says Sir Henry Thompson: "No dead body is ever placed in the soil without polluting the earth, the air and the water above and around it." But what would he and other scientists say of the placing of three or four putrifying bodies in the same grave, covered with but two to four feet of soil, and thousands of such graves upon a few acres of ground?

Many of the old burying-grounds of Europe have received so great a number of human remains as to raise the top-soil from one to four feet above the surrounding ground. Many of such burial places have been the fruitful source of epidemics and devastating plagues which have wellnigh depopulated the regions about them. Notable among these was the Cemetery of the Innocents, at Paris, the ground of which had been so filled with buried dead as to raise it some three feet above its normal level. The result was the breaking out of a terribly devastating plague.

Shakespeare seemed inspired to see this danger, as others did not in his day, when he said:

> "The very witching time of night
> When graveyards yawn and hell itself breaks out
> Contagion on this world."

Bascom relates that when the parish church in Winchinhampton, England, was rebuilt in 1843, the earth was removed to change the grade, and the superfluous black earth of the cemetery surrounding it was disposed of for manure and spread upon the adjoining fields. The result was the breaking out of an epidemic of measles, scarlet fever, and various malignant skin eruptions, and the population was nearly decimated. Many similar cases are facts in local histories.

The old English burying law required that but 135 bodies should be buried in an acre, and only one body in a grave. But in practice that number has been exceeded ten times over, indeed, almost indefinitely. In many of the cemeteries of this country, the placing of three or four bodies in one grave, opening it again for each new-comer, is coming to be no unusual thing: warning us that some of our cemeteries

are even now well on the way to those conditions which have caused such wide-spread horrors in other lands. Even beautiful Greenwood, now holding well on towards 300,000 putrifying human remains, is said to be guilty of this reprehensible and outrageous practice.

Recent scientific discoveries have proved that the germs of many infectious and contagious diseases retain their vitality and the power to spread the malady, in the grave and in the earth surrounding it. Yellow fever, cholera, small-pox, splenic fever, scarlet fever, diphtheria, and other contagious diseases can be thus communicated many years after the burial of the dead. Pasteur's researches on the etiology of charbon shows that anthracoid germs are brought to the surface by earthworms; that the earth mould over graves contains the specific germs which propagate the disease, and the same specific germs are found in the intestines of the worms.

Dr. Robert Koch, of the Imperial Sanitary Bureau, at Berlin, detected *bacillus tuberculosis*, and has no doubt but that consumption can be spread by the upturning of the soil of a grave containing the victim of tuberculosis. He also discovered the *comma bacillus* of cholera; and expressed the belief in its propagation in the grave, especially if it be moist.

The outbreak of cholera at Modena, Italy, in 1828, was shown by Professor Bianchi to be due to the upturning of the ground of burial grounds in which victims of the plague had been buried 300 years before.

Dr. Freire examined some soil from a cemetery in Brazil where victims of yellow fever had been interred. Some of this earth was dried and placed in a cage containing a guinea pig. The animal became ill and died within five days. Upon dissection all the tissues presented the characteristic changes which yellow fever brings about, and the brain and intestines were stained yellow by the infiltration of the coloring matter of the cryptococci.

While the *soil* is infested with bacteria or specific disease germs, mephitic gases, also, of the most poisonous character are passing through the soil and escaping into the atmos-

phere. Experiments prove that these gases will rise to the surface through eight or ten feet of earth, and that there is practically no limit to their power of escape. While ammonia and offensive putrid vapors are all given off from bodies decomposing in graves, carbonic acid, which makes cemetery gases so dangerous, is the largest product.

Dr. Playfair affirms that "the importation of graveyard gases entering the blood produces fever; communicated to the viscera it gives origin to diarrhœa, and may be the cause of consumption."

Already the pernicious effects of the 2,000 acres of cemetery grounds in and around Brooklyn are very manifest. The westerly winds sweep those plague spots of corruption and bear their poisonous gases and germs of typhoid fever and diphtheria to the city of Flatbush, making that the most unhealthy community contiguous to the great metropolis, and swelling the death rate to its present alarming proportions. This is only what exists under like conditions elsewhere. According to the report of the French Academy of Medicine, the "putrid emanations of Pere la Chaise, Montmartre and Montparnasse have caused frightful diseases of the throat and lungs, to which numbers of both sexes fall victims every year." "Thus a dreadful throat disease, which baffles the skill of our most experienced medical men, and which carries off its victims in a few hours, is traced to the absorption of vitiated air into the windpipe; and has been observed to rage in those quarters situated nearest to cemeteries."

In a report read before the American Medical Association by Dr. J. M. Keller, of Arkansas, in 1886, he says: "We believe that the horrid practice of earth burial has done more to propagate disease and death, and to spread desolation and pestilence over the human race than does all man's ingenuity and ignorance in every other custom or habit." He adds:

"The graveyard must be abandoned. The time has come for us to face squarely the problem how to dispose of our dead with safety to the living. The earth was made for the living, not for the dead. Pure air, pure water and pure soil

are absolutely necessary for perfect health. Only skeptics deny that the dead do poison these three essentials of human life."

Time will not now permit me to speak of the pollution of underground watercourses by the percolation through graves in which are the oozings from coffins of decomposing bodies, thus infecting wells and streams; or of the pollution by cemetary sepage into water-sheds from which large cities draw their supplies, as the Croton water-shed, in which there are said to be eighty-three cemeteries, large and small, rendering the water wholly unfit for any domestic purposes whatever. That a great sanitary reform in the disposition of the dead is a most important and urgent necessity is too evident to admit of question. Then the practical query which follows this concession is, "what shall be the *nature* of that reform? and *how* shall it be secured?" Its *nature* must be perfectly sanitary, and so appointed and employed that no contamination can occur to either air, earth or water.

Now, I am aware that a considerable number are ready with the suggestion that "Cremation is such a method." But let us look at it candidly and apart from any prejudice we may have for one particular hobby. It is the opinion of eminent jurists that should cremation threaten to become a prevalent method of disposing of the dead, inhibitory statutes would need to be enacted because of its destruction of evidences of crime, either by poisons, malpractice, assaults, or violence of any kind.

Again, suppose cremation were adopted as the prevalent method and crematories were provided with capacity equal to the burning of all the dead, New York, with its suburbs, has about 70,000 dead bodies to dispose of annually, nearly 230 bodies daily, which, if the bodies average 100 pounds each, is equal to 7,000,000 pounds of "green" human flesh to be disposed of annually, or some 30,000 pounds daily. Burn those bodies and the air will be filled with stenches so intolerable that the community would not be long in voting cremation an intolerable and unendurable nuisance, and anything but a sanitary method of disposing of the dead.

When Abraham buried Sarah in the field of Macphelah the question of sanitation was not raised. But when, in 1843, Chadwick and his associates began in London their investigations and exposures of the very unsanitary manner in which the dead of that great metropolis were disposed of, the question of sanitation was raised in so emphatic a manner as to compel public attention and secure the enactment of statutes which provided for vastly better sanitary regulations. So, when at Washington, Pa., at Fresh Pond, L. I., or anywhere else, but three or four bodies are burned in a month, the question of the sanitary effects upon the atmosphere may be scarcely thought of. But the sanitary problem would be greatly changed were all the dead of great populous communities to be burned. Here is a practical difficulty which we have never seen discussed, and for which we know of no absolutely practical solution. That cremation, to a limited extent and as far as it can be purely sanitary, is infinitely to be preferred to inhumation from a sanitary point of view, no one can deny. But there are practical obstacles, both legal and sanitary, which are very serious. And there are, also, obstacles to cremation of a sentimental character which are little if any less serious. A wise Creator and benevolent Father seems to have implanted certain sentimental instincts in the human breast in regard to a fitting deference and respect for departed loved ones, which demands to be recognized and duly respected and which cannot suffer violence without being shocked and pained. So that, however the burning of human remains may be approved as simply a sanitary method, there are manifest reasons which show that it cannot become the prevalent method of disposing of the dead. This brings me to speak of a method against which lie none of the obstacles or objections which are insuperable to the other methods. I refer to a process of *desiccation* of the dead in a finely appointed mausoleum building provided for that purpose. It is a process which is faultlessly sanitary; and, therefore, meets all the requirements in that respect that the most enthusiastic advocate for burning can demand. It provides, as no other disposition of the dead has ever provided, for

meeting and fully gratifying that tender loving sentiment respecting the treatment and disposition of the dead which is so universal.

The sanitary advantages and perfections of this method are secured by the application of advanced science in the use of appliances and in the manner of construction. Magnificent mausoleum buildings, much more grand and elegant than any the world has ever before seen, are provided with a large number of sepulchres which are formed in concrete and arranged in tiers and rows, not wholly unlike the arrangement of the spaces in a safe deposit bank. The sepulchres have one opening, which fronts a corridor, for admitting the body; and, when that is placed within, a plate glass front is hermetically sealed into that opening and this is again covered with a marble or metallic shutter or door and made secure.

There are conduits formed in the concrete, which bring dry air into the sepulchres at one end, and others which take it out at the opposite end. The air, as it passes out, is no longer dry, but is laden with gases and moisture which has absorbed from the bodies, and is now borne through conduits to a furnace, located in an annex, where it passes through the fire and is purified; so that no deleterious gases or offensive odors can ever escape into the atmosphere. The air which is drawn into and passes through the sepulchres is first rendered anhydrous in a large drying room, into which it is forced and from which it is distributed to the sepulchres, where it absorbs the moisture from the bodies in its passage.

By this process a steady current of dry air is pouring into and through the sepulchre, and doing its work most efficiently on its way. The greedy avidity with which dry air seizes and absorbs moisture is known and realized by very few. When a moderate current of dry air envelopes a human body in an air-tight sepulchre, constantly drawing the moisture out of the body and bearing it away, the dry air flowing in as the moisture-charged air and gases are drawn out, the process of desiccation goes steadily on until it is finally accomplished, in from two to five months.

After the work of desiccation is finished the air conduits are closed. As dry air only can be in the sepulchre when it is closed, and as the sepulchre is hermetically sealed and, therefore, atmospheric air cannot reach the now dessicated body, oxidation cannot be expected to ensue. There the body will repose in security and sweetness until the sounding of the resurrection trump.

The fact that by this process the moisture and gases extracted from the body are borne to the fire and cremated, and that, as the process is slow the deleterious gases and vapors pass to the furnace in small quantities at a time and are consumed with the utmost ease and safety, it is thus made the best *sanitary* disposition of the dead.

Again, it is claimed indisputably, that bacteria, microbes and disease germs of every name, live, thrive and propagate in connection with moisture; and that, deprived of moisture and subjected to dry air conditions only, they cease to exist or are entirely innocuous.

Dr. Sternberg, general director of the Hoagland Laboratory, says: "The cholera *spirillum* is destroyed in a few hours by desiccation. The typhoid *bacillus* takes a longer time; but, exposure in a dry condition to oxygen is one of the most effective ways of destroying this and other pathogenic germs." So that, if all germs of disease are not entirely borne away with the moisture and gases and consumed in the flames, and, should any remain, they are destroyed quite as effectually by the dry air in the sepulchre, which is hermetically sealed. Thus, again, rendering this a thoroughly sanitary method of disposing of the dead.

Permit me to say in conclusion, that the plan for the desiccation of human bodies in a New Mausolem, provides for great economy of space in disposing of the dead, rendering one acre of ground equal to thirty-five acres for cemetery use; provides for the most respectful and kindly care for the dead for all time; for perfect security and protection for the bodies placed therein; for guarding against entombment alive; preserves the remains for future removal or for medico-legal examination; provides a home which is equal in elegance to any princely mansion of earth and vastly more enduring, in which the dead may repose without

being disturbed; and, in addition to all these other advantages, its sanitary provisions are perfect, lacking nothing. Thus making it the best method for the sanitary disposition of the dead.

RAMIE.

By Jules Juvenet.

[*A paper read at the Stated Meeting, held October 16, 1889.*]

Dr. Isaac Norris in the Chair.

Mr. Juvenet—Mr. President, Ladies and Gentlemen:

I am here to contribute my share of labor to the success of the ramie industry, which is destined to revolutionize, ere long, the textile markets of Great Britain and America, and moreover to considerably develop the production of the Southern States, as well as the manufactures of the Northern States; but, before entering upon my subject, let me request your indulgence for attempting to address you in a language not my own.

What is ramie?

It was formerly placed by the botanists in the class of *Urtica*, but it is now called *Boehmeria*, or spearless nettle.

I will call it by no scientific name, I will simply name it the richest of all plants, for it possesses wealth of growth, wealth of development and wealth of fibre. In ordinary light ground, with a little watering now and then by rain or irrigation, no plant will grow so rapidly, no root will multiply more quickly and produce more stalks, no vegetable fibre is handsomer, richer or more silky than ramie.

It is a perennial plant, and when once put in the ground, it grows for over twenty years, without replanting; giving, according to climate, two and three crops a year; it is easy of cultivation, requiring only a soil clean and loose; it is planted in straight rows, three feet apart, in a small up-hill form; the plants must be kept very close, in order to shoot

forth straight stalks, without any branches; it grows about like willow, an average of fifteen to twenty switches, from six to eight and ten feet high, covered on the upper part with large green leaves, white underneath. Through its leaves ramie takes its nourishment from the ozone of the air. This developed part of nourishment of the plant, added to the large extensive propensity of the mother-root, from which run horizontally and down a lot of rhizomes and small roots, explain the extraordinary vitality of the plant, and its three and four crops a year in some countries. The Chinese alone have, for a thousand years past, extensively cultivated the ramie plant; before them, the Egyptians were shrouding their dead in magnificent winding sheets of ramie, which to this day are found in the bandages of their mummies. As a textile, therefore, ramie is not precisely a new thing.

How comes the industrial world of this industrial century to be thus backward in introducing practically a plant capable of yielding such important returns and which was made known in Europe by Professor Roseburgh, Director of the Botanical Garden of Calcutta, as long ago as 1803?

The reason is that machinery has been required to do the handwork of the Chinese. No machine can do it at once practically; it requires machinery good for planters, enabling mere separation of the crude bark of the stalks, leaving to industry and chemical agents the task of eliminating the gummy and resinous matters encasing the fibre.

It is then not only a practical machine to peel the bark from the ramie stalks that we want, but also a cheap chemical process to dissolve the foreign matters around the white textile, which has also to be spun on special machinery. Only the perfect knowledge of these connected operations, managed in a business way, will assure in this country the success of the ramie industry.

In a rapid manner I have already explained above the mode of culture of the plant, and I am now preparing to be distributed over all the Southern States a pamphlet giving detailed information on the different phases of the ramie culture.

There is no doubt that Southern planters will go extensively into said culture, when we have here in Philadelphia mills to turn their raw products of ramie into thread finer and stronger than the finest flax thread.

After the cultivation of ramie we have to know how to harvest it, or decorticate it, then to bleach the same and spin it.

It is these three operations that I want to explain here, and on which we experimented last week at Bloomsdale Farm, near Bristol, Pa.

A five-acre field was planted with ramie there in May of this year, for experimentation only, because, in a general way, the ramie culture is not well adapted to this section, the frost here killing the root during the winter; but Philadelphia is an enterprising textile place, and wants to have at hand every element of success. To illustrate what has been done at Bloomsdale, I bring here some green ramie stalks from that place.

A minimum of fifteen of these are growing in a bunch on each plant, and there are 10,000 plants in one acre, say from 150,000 to 200,000 stalks to the acre; an efficient machine had then to be devised to harvest rapidly such a number of stalks.

The decortication or peeling of the fibre from the stalk is done in the following way: (1) By beaters to strip the leaves; (2) A crusher to break the woody part; and (3) Other beaters to knock out the wood and get the bark in the way I show you here, which, henceforth, will be the marketable article for planters of ramie. Then the chemical treatment will come in and dissolve the gummy matters in order to get the white textile, which will be spun in Philadelphia. The crude bark is chemically composed as follows:

The cellular portion, embracing cellulose, paracellulose, metacellulose; then vasculose, pectose, cutose, albuminous substances, pectate of lime, some mineral matters in very small quantities.

The cellulose, of which there is about seventy per cent. in Louisiana ramie, is the fibre itself. We have to keep it intact, to get our pure ramie textile, henceforth we have,

then, to eliminate the vasculose, pectose and cutose more or less according to the purposes for which the material is wanted, or for cordage, lace, or damask. If it is for cordage, cutose only must be dissolved, and if for lace or damask, vasculose, pectose and cutose must be dissolved to leave the cellulose or fibre entirely pure.

As a guide, it should be noted, that boiling diluted hydrochloric acid dissolves pectate of lime, setting free pectic acid, which may be neutralized by an alkali, and it also transforms pectose into pectine, which can be precipitated by alcohol.

Cellulose is dissolved by cupro-ammonium solution; and boiling hydrochloric acid renders paracellulose soluble in cupro-ammonium. Bi-hydrated sulphuric acid dissolves cellulose substances. A boiling solution of potassa dissolves cutose, and under pressure it dissolves vasculose. Diluted nitric acid renders vasculose soluble in alkaline solutions.

The bleaching process consists then in applying the chemical agents in suitable proportions to dissolve slowly the foreign matters we want to get rid of, which are then washed away in running water. The bleaching being done, the fibre is then ready for the mill—but no spinning mill for ramie exists as yet in the United States, and the cotton, wool, flax and hemp spinners cannot put ramie on their machinery. It requires from the softener to the spinning-frame, provided with numerous small spindles, a series of from eight to ten machines well connected together. When the ramie has passed through these machines it is then turned into strong, fine, glossy thread, from No. 10 to No. 80, which any weaver of the land may use with advantage.

The problem of the practical utilization of ramie, is at last on the very road to success in all its branches; this has not been obtained without study and loss of money and time.

To agriculturists, I will say, that I have often weighed ramie stalks, grown by myself, in Louisiana; I used to take 150 stalks fully grown, about six feet high; those 150 stalks representing the minimum crop of ten plants. It gave me the following figures:

Plants.	*Stalks.*	*Weight of Green Stalks with Leaves.*	*Weight of Green Stalks without Leaves.*	*Crude Fibre, Wet.*	*Crude Fibre, Dry.*	*Bleached Fibre*
		lbs.	*lbs.*	*lbs.*	*lbs.*	*oz*
10	150	49	29	6	1	7

There are 10,000 plants in one acre, or 1,000 times more than the above table, say 1,000 pounds of crude bark or fibre, dry, and 437 pounds of bleached ramie, per crop, and as there will be two crops if not three yearly, the gross return of an acre of ramie can be easily calculated, when I add that crude bark of ramie, dried and baled, is worth from three to five cents a pound, according to quality. I will say, also, that there is in the South not much danger of bad crops of ramie, because it is easy of cultivation, and there is no fear of frost, or of cotton worm, on account of the tannin contained in the plant, on which account, insects rarely attack ramie plants.

This new product of the Southern States being brought to Philadelphia to be bleached and spun, will advance the welfare of this city as has the carpet trade.

Philadelphia is now the greatest carpet-making city in the world. Only about thirty years ago the industry here had its beginning with John Bromley, who worked two looms in a small building. There are now 172 establishments, occupying over 200 large structures, working 7,350 looms and employing 17,800 workmen. They produced last year 71,500,000 yards of carpet, worth nearly $48,000,000. And the price to the consumer has been reduced about one-half.

When ramie shall be woven alone, or with cotton, wool, flax or silk, as samples here, by every mill in the country, the public at large will find:

That ramie has twice as great strength as flax and hemp, that it washes much better than any other textile and becomes whiter than hemp and flax.

That ramie, when properly worked, has the lustre of silk, to such an extent that it is used for many fancy articles, dresses, fine passementeries, portières, plush, etc.

That ramie is more hygienic than flax, hemp or cotton, and that its use is recommended in several hospitals for dressing wounds.

That ramie does not rot in water, and that on this account it is in great demand in the Navy for sails, cordage, fishing tackle, and wherever the quality of resistance to the atmosphere and water is needed.

With all the elements of success above explained, and even in the incessant and daily progress which this century makes in all things, commerce, industry, literature, art, science, a new industry of any scope and importance necessitates for rapid development a large centre of production and consumption. Philadelphia, I hope, will be this centre for the ramie production of the South, and the ramie manufacture and consumption for the whole of this great Republic.

REVIEW OF THEORIES OF ELECTRICAL ACTION.*

By Professor H. S. Carhart.

The Physics Section of this Association congratulates itself because it deals with topics of the most lively and general interest, not only from a practical point of view, but still more from a theoretical one. Even popular interest in electricity is now wellnigh universal. Its applications increase with such prodigious rapidity that only experts can keep pace with them. At the same time the developments in pure electrical theory are such as to astound the intelligent layman and to inflame the imagination of the most profound philosopher.

Of the practical applications of electricity it is not necessary to speak. They bear witness of themselves. A million electric lamps nightly make more splendid the lustrous name of Faraday; a million messages daily, over land and under sea, serve to emphasize the value of Joseph Henry's contribution to modern civilization. Blot out these two names alone from the galaxy of stars that shine in the

* Address by Professor Carhart, Vice-President Section B, American Association for the Advancement of Science, delivered at the annual meeting, Toronto, August 28, 1889. Abstract from *The Electrical Engineer*.

physical firmament, take from the world the benefits of their investigations, and the civilization of the present would become impossible. The value of the purely scientific work of such men is attested by the resulting well-being, comfort and happiness of mankind.

But the mind can never rest satisfied with the facts and applications of a science, however interesting and useful they may be. It feels an inward impulse to link the facts into a related whole, to inquire into their causes, to frame a satisfactory theory of their correlation, and so to build on them a true science.

It is, indeed, interesting to study the history of any scientific doctrine and to trace its development from the crude notions of its earliest stages to the more refined conceptions of later periods, comporting indefinitely better with the marvellous processes of nature. Such a history we have in the views which have been held regarding the nature and action of electricity. The transition from the glutinous effluvium of the sagacious Robert Boyle to the magnetic and electric waves of the present, traversing the omnipresent ether with the velocity of light, is not an easy one to make, even in a period of 200 years.

For more than twenty centuries natural philosophers had nothing better than the emission theory to account for the attraction exhibited by rubbed amber and other similar substances. Their notion was that the rubbing of the amber caused it to emit an effluvium which returned again to its source and carried light bodies back with it.

In one respect this fanciful attempt to explain electrical attraction deserves commendation, for it evinces a mental inaptitude to account for physical actions "at a distance," or without some intermediate agency. Later philosophers, satisfied perhaps too easily with mathematical explanations founded on the observed laws of attraction and repulsion, and not demanding a medium, did not feel the same intellectual necessity of filling the space between bodies acting on one another, either with emanations from those bodies or with an invisible, imponderable medium, suspected by no sense of man, but required only to meet a demand of his

highest intelligence. For when the Newtonian philosophy had made some progress, the doctrine of unctuous effluvia was given up, and physicists acquiesced in the unexplained principle of attraction and repulsion as properties of certain bodies communicated to them by the Divine Being, the mechanism of which they scarcely attempted to explain.

"Many superficial philosophers thought they had given a very good account of electricity, cohesion and magnetism by calling them particular species of attraction peculiar to certain bodies."*

The discovery by Stephen Grey that "the electric virtue" could be conveyed along a wire for several hundred feet without sensible diminution, and the invention of the Leyden jar by Kleist, or Cuneus, had the effect of annihilating many mushroom theories constructed on the slimmest basis of facts. The latter discovery disclosed a power in electricity not previously suspected, and excited the greatest interest in both Europe and America.

At this period Franklin turned his attention to the subject, and "spent more time in diversifying facts and less in refining upon theory" than some of his European contemporaries. In fact, he tells us that he was never before engaged in any study that so totally engrossed his attention and his time. His discovery that the two electricities are always excited in equal quantities, that the charge resides on the glass and not on the coatings of the Leyden jar, and his experimental identification of lightning with frictional electricity, excited the liveliest interest abroad, and secured for him the Copley medal of the Royal Society; while his theory of positive and negative electricity made a permanent addition to the nomenclature of the science. His conceit that a turkey, killed with the discharge of a battery of jars, was uncommonly tender eating, a discovery gravely communicated to the Royal Society by William Watson, is not so well known, and does not appear up to the present to have been verified.

We cannot agree with him, I am sure, when he says:

---

* Priestley's *Hist. of Elec.*, vol. ii, p. 18.

"Nor is it of much importance for us to know the manner in which nature executes her laws; it is enough if we know the laws themselves."

For the pursuit of the manner in which nature executes her laws is the distinguishing characteristic of the science of the present day. It has led to most brilliant discoveries, and bids fair to do more than all other agencies combined to show the intimate and necessary relations existing between the different branches of physics. We need to be reminded often that accumulated facts do not constitute a science; and that utility is not the highest reward of scientific pursuits.

A bit of polished marble, plucked from the ruins of the Roman Palatine Hill, is an interesting relic; but how much more interesting to reconstruct the palace of Nero and to see this fluted marble in its proper and designed relation to the whole, of which it was once a necessary part. Science is constructive. Laws are derived from an attentive consideration of facts; generalizations group laws under broader relationships; and great principles unite all together into one related, impressive whole.

From the time when the famous Boyle caught sight of a faint glimmer of electric light to the present, physicists have been in pursuit of the connection between light and electricity. As early as Newton's time, the ether was conceived by some to be a subtle medium confined to very small distances from the surfaces of bodies, and to be the chief agent in all electrical phenomena. "But," says Priestley,* "the far greater number of philosophers suppose, and with the greatest probability, that there is a fluid, *sui generis*, principally concerned in the business of electricity. They seem, however, though perhaps without reason, entirely to overlook Sir Isaac Newton's ether; or if they do not suppose it to be wholly unconcerned, they allow it only a secondary and subordinate part to act in this drama." Among the branches of knowledge that this writer recommends as likely to be of especial service in the study of

---

* *Hist. of Elec.* vol. ii, p. 22.

electricity is the doctrine of light and colors. The invention of the voltaic battery, and Sir Humphry Davy's celebrated experiment in producing the electric arc, stimulated inquiry in this same direction. Mrs. Somerville, Morrichini and others sought to produce magnetism by means of sunlight, but ultimately, as is now known, without success. Notwithstanding these negative results, Faraday had such a "strong persuasion derived from philosophical considerations" of a direct relation between light and electricity, that he resumed the inquiry in a most searching manner, with the happy result of discovering the rotation of the plane of polarization of light by means of magnetism.

"Thus is established," he says,* "a true, direct relation and dependence between light and the magnetic and electric forces; and thus a great addition [is] made to the facts and considerations which tend to prove that all natural forces are tied together, and have one common origin."

It was thus reserved for Faraday to make those discoveries and to obtain that insight into electric and magnetic action which were needed by his great disciple and interpreter, Maxwell, to construct a most marvellous theory of the connection between these two departments of physical science.

Respecting the failures to obtain magnetism from the direct action of sunlight, to which allusion has been made, Maxwell says that we should not expect a different result, because the distinction between magnetic north and south is one of direction merely; that there is nothing in magnetism indicating such opposition of properties as is seen at the positive and negative poles of a battery in electrolysis; that even right and left-handed circularly-polarized light cannot be considered the analogue of the two poles of a magnet, for the two polarized rays when combined do not neutralize each other, but produce plane-polarized light.

It may be said, however, that if a right-handed circularly-polarized ray produces magnetism in one direction, and a left-handed ray in the opposite, then the combination of the

* *Exp. Researches*, 2,221.

two rays may neutralize their magnetic effect, inasmuch as plane-polarized light may have no magnetic influence. Professor J. J. Thomson has lately shown mathematically that a circularly-polarized ray does have a magnetic effect, but that it is so small, even with strong sunlight, as to be much beyond the limits of experiments; and Mr. Shelford Bidwell has produced a bar of iron in such an exquisitely sensitive magnetic state, that magnetic changes are certainly produced in it by the direct action of light. This he has secured by rendering the bar more susceptible to magnetic influences in one direction than the other. We may not, I venture to affirm, be without hope that magnetism and electric currents may yet be evoked by the direct agency of sunlight.

Faraday was deeply convinced that space had magnetic properties, and that the space or medium around a magnet is as essential as the magnet itself, being a part of the complete magnetic system. To him all magnetic and electric action took place by contiguous particles along lines of force. "What that magnetic medium, deprived of all material substance, may be, I cannot tell," he says,* "perhaps the ether." No doubt existed in Faraday's mind that these lines represent a state of tension; but whether that tension is a *static* state in the ether, or whether it is *dynamic*, resembling the lines of flow of a current between the poles of a battery immersed in a conducting fluid, was uncertain. He inclined, however, to the latter view. He was thus lead to advocate, though not without hesitation, the physical nature of lines of force.

Faraday's discoveries and his method of regarding all magnetic and electric actions as propagated through a medium by means of contiguous parts have been of the utmost productiveness. They have revolutionized the science of electricity, and have been the most potent factors in the genesis of a theory, including all radiant energy, which has recently received such remarkable and conclusive confirmation. His name has become almost a household

---

* *Exp. Researches*, 3,277.

word. His earnest, unselfish life has added unnumbered millions to the world's wealth. His ideas and words, which have been instruments in the hands of philosophers, have become the current coin of the commercial tyro, who talks as glibly about lines of force and the magnetic circuit as if he really knew something about them.

Fruitful as Faraday's ideas were, they yet awaited a mathematical interpreter for their highest development. A good Providence sent James Clerk Maxwell, whose brilliant mathematical ability was equalled by his philosophic insight, his poetic feeling and imagination, his profound sincerity and his great sympathy with nature.

To appreciate Maxwell's relation to theories of electrical action, it is desirable to take a retrospect of the views that have been held regarding its nature. Three periods in the history of these views may readily be distinguished. The first was introduced by Dr. Gilbert in 1600, and it lasted for about 225 years. The little that was known previous to Gilbert constitutes only the preface or introduction to the history proper. Nearly three-fourths of this period was utterly barren and unfruitful. It knew nothing better than unctuous effluvia and electric atmospheres. In the latter half of the period the Newtonian philosophy had become the orthodox doctrine. The great success attending the mathematical investigations, founded upon the law of inverse squares, naturally carried with it the acceptance of the underlying hypothesis of "action at a distance." There were not lacking, indeed, men of deeper philosophic insight who denied this doctrine, which they looked upon as entirely unphilosophical and which must utterly bar the way to any inquiry into the process by which the law is executed. Action at a distance by attraction or repulsion, varying inversely as the square of that distance, means an ultimate fact not admitting of further analysis.

The second period was one of contention. It began, not with the important discovery of current electricity, nor of the electro-magnet, but with the philosophical methods and concepts of Faraday. The physical postulates of the mathematical school were entirely alien to the views which

he adopted. "Faraday, in his mind's eye, saw lines of force traversing all space where the mathematicians saw centres of forces attracting at a distance; Faraday saw a medium where they saw nothing but distance; Faraday sought the seat of the phenomena in real actions going on in the medium, they were satisfied that they had found it in a power of action at a distance impressed on the electric fluids."* Prior to Faraday the supporters of a medium to explain electric and magnetic action were always thrown out of court for lack of evidence; Faraday gave them a legal standing by furnishing the facts and evidence on which they could well afford to base their case.

The corpuscular theory of light, which had shown such remarkable vitality, was now in the last stages of a fatal disease, due to indigestion and lack of assimilation. Foucault finished it off in 1865 with his crucical experiment to decide upon the relative velocity of light in the air and water. The undulatory theory was thus fully established, and the doctrine of radiant energy in general began to be clearly apprehended. The grand generalization of the conservation of energy was looming up all along the horizon of science, as the towers and spires of a great city appear to rise out of the sea to a traveller approaching the land. Victory was ready to perch on the banners of an army contending for the ether doctrine—not a decimated army, but one constantly augmenting in numbers by deserters from the enemy. At this period, sixteen years ago, appeared the epoch-making book of Maxwell on *Electricity and Magnetism.* Its author professes only to translate Faraday's ideas into mathematical language; but he did vastly more than this. He demonstrated mathematically that the properties of the medium required to transmit electro-magnetic action are identical with those of luminiferous ether. It would be unphilosophical, he remarks, to fill all space with a new medium whenever any new phenomenon is to explained; and since two branches of science had independently suggested a medium requiring the same properties to account

---

* *Maxwell's Elec. and Mag.*, p. x.

for the same phenomena in each, the evidence for the existence of a single medium for both kinds of physical phenomena was thereby greatly strengthened. The step from identity of the medium to identity of phenomena, that is, that light itself is an electro-magnetic phenomenon, though it may now seem to be a short one, must nevertheless, upon careful consideration, always be accepted as evidence of the greatest genius. To walk in Maxwell's footsteps now and take the very steps he took is one thing, and a comparatively easy one; but to make original explorations into unknown regions of nature, and to tread where no human being has ever before set foot, is quite another thing. The electro-magnetic theory of light must be regarded as a great generalization, inferior only to that greatest one of all time—the conservation of energy.

The principal criteria upon which Maxwell relied for the confirmation of his theory may be briefly enumerated:

(1) An electro-magnetic wave or undulation is propagated through the ether with a velocity equal to the ratio of the electro-magnetic to the electro-static unit of quantity. If light is an electro-magnetic phenomenon, its velocity must also be equal to this same ratio. The very close approximation of the one to the other, as determined by a variety of methods, has been known for some time.

(2) The specific inductive capacity, K, of any transparent dielectric should equal the square of its index of refraction. The discrepancies at this point are so great that all one can say in the most favorable case is that K is the most important term in the expression for the refractive index, while in other cases no confirmation whatever can be drawn from this class of evidence.

(3) The magnetic and electric disturbances are both at right angles to the direction of propagation of the wave and at right angles to each other. The mathematical form of the disturbance agrees with that which constitutes light in being transverse to the direction of propagation. Further, the *electric* disturbance should be perpendicular to the plane of polarization of plane-polerized light.

(4) In non-conductors the disturbance should consist of

electric displacements, but in conductors it should give rise both to electric displacements and electric currents by which the undulations are absorbed by the medium. Most transparent bodies, it is true, are good insulators, and all good conductors are opaque. The degree of opacity is, however, far from being proportional to the conductivity.

(5) But perhaps the most important criterion of all is the one relating to the very existence itself of a medium. Such a test lies in the *time* element involved in transmission from point to point. Since energy is transmitted from a luminous body, as the source, to another body, which may absorb it, then plainly, if time is required for the transmission, the energy must reside in the medium by which the transmission is effected during the interval between the emission and the absorption. In the emission theory the light corpuscles are the receptacles of the energy and carry it with them in their flight. According to the undulatory theory, the medium filling all space is the receptacle of the energy, and passes it along from point to point by the action of contiguous parts.

Foucault's *experimentum crucis* proved the emission theory untenable. Roemer's observation of the retardation of the eclipses of Jupiter's satellites, when the earth is moving away from Jupiter, is, therefore, a confirmation of the undulatory theory of light and, in consequence, a demonstration of the existence of the luminiferous ether.

At this point the history of the nature of electrical action touches upon the third period.

The period upon which we have just entered may not inappropriately be called the period of confirmation. Nothing further appears to be necessary for the complete demonstration and establishment of the electro-magnetic theory of light. The noteworthy experiments of Professor Hertz, of Carlsruhe, are known to all. Rightly conceiving that the reality of electro-magnetic waves would be best established by the same experiments which would also establish the fundamental identity of such undulations with those of light, he had recourse to the principle of resonance or sympathetic vibrations for the detection of these long-period

waves. By a device no less remarkable for its simplicity than its effectiveness he produced electrical oscillations of such rapidity that the waves in the surrounding region were short enough to be measured. This he accomplished by attaching to the secondary terminals of an induction coil two rectangular sheets of metal, each supplied with a short, stout wire ending in a small ball. The balls were brought near each other and the discharges of the coil took place between them. Under these conditions the discharge is oscillatory, and the period may be calculated by the formula of Sir Wm. Thomson, published in 1853.*

The receiving apparatus is also of the simplest design, consisting ordinarily of a circle of wire, interrupted at a point with an adjustable opening, and of such dimensions that the waves passing through the circle may set up electrical oscillations in it, synchronizing with those of the transmitting apparatus. The passage of sparks across the narrow opening of the circle indicates an electrical flow; and the necessity of adjusting the size of the circle in order to obtain this flow proves that the forces acting are periodic. The receiving apparatus must in fact be tuned so that the period of an electrical oscillation in it shall correspond with the external impulses absorbed. The intensity of the electric and magnetic disturbances is indicated by the relative length of sparks obtainable.

Equipped with this apparatus, which was installed in a large lecture hall, Hertz found not only that his tuned receiver responded to the impulses of the transmitter in the precise manner pointed out by theory, but that the sparks showed a series of maximum and minimum values recurring in periodic order as the receiver was carried further away from the source of the disturbances. The astounding fact was thus brought out that these electro-magnetic waves were reflected from the thick wall of the room, and that the combination of the direct and reflected systems produced stationary waves with loops and nodes that could be traced out by the responsive circle of wire. In this manner wave

---

* *Math. and Phys. Papers*, vol. i, page 540.

lengths were measured down to sixty cms., and the *time element* was experimentally detected in the propagation of electro-static and electro-dynamic induction. It was demonstrated that the disturbances producing the waves are at right angles to direction of propagation, as Maxwell predicted, and as interference phenomena show them to be in light. Hertz has also found an electro-dynamic shadow cast by an iron post; he has verified the laws of reflection from plane and concave metallic reflectors, and has shown that electric waves suffer polarization and refraction in a manner exactly analogous to light. Professor Fitzgerald, of Dublin, has added another confirmation of Maxwell's doctrine, demonstrating that the *electric* disturbance is perpendicular to the plane of polarization, as Maxwell's equations require. Finally, the velocity of propagation of these electro-dynamic waves is found to be the same as the velocity of light. Thus not only have all of Maxwell's criteria, except the second, abundantly confirmed the judgment of the great physicist, but other proofs have been added. Electro-magnetic waves are therefore not merely like light, but they are light. Or perhaps, to speak more exactly, all radiant energy is transmitted as electro-magnetic waves in the luminiferous ether. Electricity has thus annexed the entire domain of light and radiant heat; and, as Professor Lodge says, "has become a truly imperial realm." The difference of wave length in the three classes of phenomena is not a fundamental one. Increase the rate of the electrical oscillations a million-fold in Hertz's experiments, and the waves would not merely resemble light—they would be light. A wire through which such oscillations are surging back and forth would glow with light. Even the long heat waves would be absent, and only those producing the sensations of light and color would remain.

It will be observed that the oscillations of an electric discharge constitute the point of departure for the admirable researches of Hertz; and it is a matter in which we may modestly take a bit of national pride that the first case of electric oscillations was discovered by an American physicist. The oscillatory character of the Leyden jar dis-

charge was demonstrated by Joseph Henry, in 1832, by means of the magnetic effects produced in small steel needles. It was not until twenty-one years later that Sir Wm. Thomson published the complete mathematical theory of such oscillations. They have since been observed directly by means of a rotating mirror. Dr. Oliver Lodge has lately shown that they rotate the plane of polarization of light in one direction and then in the other as they surge back and forth. He has also reduced the number of oscillations from several millions per second to a few hundred by increasing the capacity and the self-induction. The discharge then vibrates within the limits of audibility and produces a musical note.

The well-known experiment of Henry, in which he observed an induction current in a wire stretched parallel to and distant thirty feet from one which served to discharge a Leyden jar, is now seen to have been a case of resonance; that is, the absorption of electric waves by a conductor, producing currents therein. And it is an evidence of the great genius of Henry that he saw, somewhat dimly it may be, but still with a certain degree of rational apprehension, that the induction was transmitted across the intervening space with a velocity comparable only to that of light. He had perchance the divine touch of genius necessary for the great discovery of electro-magnetic waves coursing through the ether; but the way leading to this important physical fact had not then been sufficiently prepared, and its discovery was impossible.

Waves, similar to those from a Leyden jar discharge, but of longer period, are sent out from a wire conveying alternating currents. We must conceive of such a wire not simply as affected internally or even superficially by the electric energy surging through it, but as the source from which pulsate outward through the limitless ether great waves of electro-magnetic disturbance. For 300 complete alternations per second, these waves are a million metres, or over 600 miles, in length. They present a marked contrast with the waves corresponding to the D lines of the spectrum, which are only about one five-millionth of a millimetre long.

These long waves from an alternating current represent energy. Through space it is conveyed with the velocity of light, and through other non-conductors or dielectrics with a smaller velocity, precisely as in the case of the radiant energy of light or heat. Henceforth the complete equation for the distribution of energy by means of alternating currents must include a term to express the radiation from the circuit. It may indeed be found that this term represents no inconsiderable part of the energy communicated to the wire in the case of very rapid alternations.

Thus we see that the ether plays a magnificent role in what may be called its dynamic relation to electric displacements. In its capacity as a reservoir of static or potential energy its agency has been better understood for a considerable period. When a continuous current begins to flow through a closed circuit, a single wave travels out from the conductor; and during its progress, while the current is approaching its constant value, the inclosing ether is assuming its condition of static repose under stress. The whole ether, extending indefinitely outward from the conductor, is profoundly modified.

We know how to map out the circular lines of force about it by means of iron filings; but the iron serves only to show what has already taken place in the ether before the filings are brought into the field. Every little iron particle becomes a magnet, with all the north-seeking poles stretching in one direction round the wire, and all the south-seeking poles in the other. What the mechanism of the stress, or the motion in the ether to produce these effects, may be, we do not know; but we do know that these lines of force are all subject to a tension tending to shorten them, and that they are mutually repellent laterally. When a current is sent through a conductor, the ether is expanded in concentric cylindrical layers about any straight portions of the circuit, and becomes the reservoir of potential energy.

As soon as the current, which maintains this state of tension, ceases to flow, the stretched ether collapses upon the conductor, yielding up its energy in the form of self-induction. If a steady current is conceived as the setting-

up and breaking-down of a static difference of potential energy at infinitesimal intervals of time, then the energy transmitted may depend upon a similar formation and decay of the static stress in the encompassing ether. The conductor is but the core of an electro-magnetic disturbance in the surrounding medium; and it may be that the enormous energy which a small copper wire can apparently convey is in reality transmitted by the invisible medium.

From this brief review of the theory of electric action it will be quite evident that henceforth the language applied to electrical phenomena must always include the luminiferous ether as a prominent term. The experiments of Hertz have made it impossible to explain electrical facts without taking this invisible medium into account. There is no such thing as electric or magnetic action at a distance. The ether is always an essential part of that complex system, the interactions of which manifest themselves as electric or magnetic phenomena.

As the ear responds to the slow oscillations of an electric discharge through the intermediate agency of heat, so the eye of the mind responds to those more rapid oscillations, the existence of which has been demonstrated by experiment. No less clearly does the magnetic field appear as a system of lines of stress in the ambient ether. Definiteness has taken the place of the metaphysical speculations of earlier times. Complete ignorance has, at least, been superseded by half knowledge. We may not yet affirm with Edlund that the ether *is* electricity, but we are doubtless nearer a solution of this old problem than ever before.

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, Ocotber 15, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 15, 1889.

MR. T. C. PALMER, Vice-President, in the Chair.

Members present: Dr. L. B. Hall, Dr. Wm. H. Wahl, Prof. N. Wiley Thomas, Mr. W. W. McFarlane, Mr. C. J. Semper, Mr. Lee K. Frankel, Mr. Reuben Haines, Mr. A Weikel, Mr. J. H. Eastwick, Mr. F. C. Lewin and a number of visitors.

The following gentlemen were nominated for membership in the Section: Mr. Geo. L. Norris, Pencoyd, Pa.; Mr. Hugh A. Galt, 1011 Spruce Street, Philadelphia; Mr. Lucius E. Williams, Swarthmore College, Swarthmore, Pa.; Mr. Hermann Schanche, Gray's Ferry Chemical Works, Philadelphia.

Dr. Wahl made some remarks on the industrial production of aluminium by electrolysis, supplementing his comments of last meeting. He referred to the process of M. Adolphe Minet, in operation industrially at Creil (Oise), France, and which in essential parts was identical with that of Mr. Hall. Mr. Minet electrolyzes a bath composed of forty per cent. of cryolite and sixty per cent. of chloride of sodium, maintained in the state of igneous fusion. The bath is continually regenerated by additions of alumina (or bauxite). The interesting point in considering the two processes, the speaker stated, was the different explanations of the operations taking place in the bath under the action of the electric current upon substantially the same components; Hall claiming that the alumina undergoes electrolysis, the solvent fluorides being unaffected, and Minet that the fluorides are electrolyzed, the liberated fluorine acting upon the alumina, to form fresh fluoride, thus maintaining the bath, the explanation of M. Minet, the speaker held, to be the rational one. Adjourned.

WM. C. DAY, *Secretary.*

NOTES AND COMMENTS.

ENGINEERING.

BRIDGING THE ENGLISH CHANNEL.—One of the papers read before the meeting of the Iron and Steel Institute, at its recent meeting in Paris, was fowarded by M. Schneider, of Creuzot, and M. Hersent, ex-President of the French Civil Engineers' Society, on the Channel Bridge, and gave an elaborate account of the scheme. The route chosen as the line, stretching over the shallowest parts of the Channel and connecting the shores where closest to each other, commences at a point near Cape Gris Nez, passes over the Colbert and Varne banks, and terminates near Folkestone. The Colbart and Varne banks are situated near the centre of the Channel, about six kilometres (3·72 miles) apart, the depth of the water at that point not exceeding seven or eight metres (twenty-three to twenty-six feet) at low water, and are separated from each other by a depression about twenty-five metres to twenty-seven metres deep. Between the Varne and the British coast the depth does not exceed twenty-nine metres, but near Colbart the bottom sinks somewhat abruptly down to forty metres. It then attains fifty-five metres (180 feet) about midway across, when it begins gradually to rise. In these parts the chief difficulties would be encountered in laying the foundatinns. The result of repeated experiments is that the ground is found to be sufficiently solid to support very extensive works, and the borings lately made in connection with the proposed tunnel have confirmed preceding experiments as to the position and nature of the bottom as published by M. de Gamond. More precise inquiries will be necessary, when the works are proceeded with, as regards each pier, in order to be in a position to solve each detail beforehand. The metal to be used is steel. The extensive use of it made lately, both in France and abroad, notably in the Forth Bridge, removes every doubt as to the feasibility of dispensing with about fifty per cent. in weight by the use of steel, while insuring the same degree of safety. The amount of metal and machinery to be provided would represent an aggregate weight of about 1,000,000 tons, the assumption being that each country will have to supply one-half of this amount. A powerful impulse would, for a long period, be given to national industry. The many improvements made in the art of bridge building warrant every hope of success in an attempt to turn out spans of metal 500 metres (1,640 feet*) in length across the Channel, supported by columns resting at different depths on the bottom of the sea. A rough calculation gives, with reasonable certainty, 380,000,000f. for masonry supports, and 480,000,000f. for the metallic superstructure—in all, 880,000,000f. or £34,400,000 ($170,000,000). The works for the tunnel and the railways of both countries would have to be planned later on, in agreement with the companies whose lines would lead up to the bridge. The time required for the undertaking may be fixed at about ten years. The whole of the pillars

* The spans of the Forth Bridge are 1,700 feet.

will occupy a little over one twelfth of the section of the Channel. This reduction of the section of the Channel is not likely to exercise a notable influence on the erosion of the bottom, or to bring about an appreciable increase of the speed of the flood and ebb tides. The distance between the piers, fixed at 500 and 300 metres for the large spans, will not be less than 200 and 100 metres respectively for the small ones, and will be sufficient to prevent their proving an obstacle to the free navigation of sailing vessels. As regards steamships, no such danger is to be apprehended, as the current, which would become a little faster in the centre of the open spans, would carry floating bodies, even disabled vessels, towards that part, and prevent their ever touching the bridge. Owing to these distances and dimensions, the piers would, in no way, modify the conditions of navigation in the Channel, and would not constitute an appreciable obstacle to navigation in general.

As for the metallic superstructure, the metal columns firmly placed upon the platforms of the supporting piers of masonry are of a distinctly cylindrical shape, and vary in height between 40 and 42·78 metres, and on them will be placed the main girders of the bridge. There will thus be between the lower part of the beams and the level of the sea at low water a free space, varying in height between 61 and 63·78 metres, which height at high water will be reduced to 54 and 56·78 metres respectively (177 feet). This height is amply sufficient for the passage of vessels of whatsoever description or tonnage. By placing the flooring upon vertical cylindrical columns the minimum height of 54 metres is kept throughout the whole width of the span, a result not achieved in the bridge over the Forth. The girders are to be simple, unlatticed, and trussed, so as to insure the proper distribution of all stresses. The level of the permanent way is 72 metres above the low-water level. The height might have been reduced by arranging the permanent way in the lower portion of the bridge, but in that case it would have been necessary to make the cross beams a great deal larger and consequently heavier. By raising the permanent way, on the contrary, a marked economy is attainable which will certainly not be absorbed by increased expenses involved by the necessity of erecting viaducts at both ends of the bridge. There will be a double set of rails, and the width of the flooring proper will be eight metres. The width of the bridge is variable, the greatest distance being between the axes of the main girders, twenty-five metres, a space necessary to insure the stability of the structure under the action of violent gusts of wind. The roadways are of the ordinary width of fifteen metres between the axes and the rails, the latter set in grooves to obviate accidents The floor, made of ribbed sheet-iron, is to cover the bridge throughout its length, so as to make every part accessible to the men appointed for its supervision. Between and outside of the roadways pavements are provided for the men to stand on, and thus keep out of the way of passing trains. On the flooring may be set up refuges, stations for the guards, signal boxes, switches, etc All these arrangements can be multiplied according to the requirements of the traffic, and scattered over any convenient points and spans of the piers. Lighthouses may he erected to indicate obstacles to be avoided. The various

kinds of lights used in lighthouses may also serve to indicate to shippers the distance from the Colbart and Varne banks. It would have been easy to establish a bridge with four lines of rails, instead of two, but the probable development of the traffic did not appear to warrant any increase of outlay in that direction. A road for ordinary vehicles is also superfluous, as goods will always be carried by rail. To meet objections from a military point of view, arrangements could be made for making the span at either end of the bridge unfit for use; the two end spans, notably, which are in contact with the abutments, might be removable or revolve. The paper proceeded to give a minute account of the mode of construction, and was accompanied by plans. The total length at this site would be nearly twenty-five miles. L. M. H.

CHEMISTRY.

ON THE BEHAVIOR OF WOOD AND CELLULOSE UNDER INCREASED PRESSURE AND AT ELEVATED TEMPERATURES IN THE PRESENCE OF WATER.—The increasing use of pure cellulose from wood in the manufacture of paper, has made it desirable to ascertain how wood withstands higher temperatures and increased pressure, (1) in the presence of water, (2) of dilute acids, (3) of soda solution and (4) of acid sulphate of potassium. And of equal importance was it to ascertain how pure cellulose stood the same conditions, so as to gain some information with regard to the decomposition products of the so-called incrusting substances. H. Tauss has carried out a series of tests upon pure Swedish filter-paper on the one hand and upon fine shavings of beech-wood and fir-wood on the other hand. His results were as follows: Cellulose paper, even of the purest variety, gives, on boiling with distilled water under ordinary atmospheric pressure, traces of sugar. Under increased pressure, the amount of sugar in solution increases, but only at twenty atmospheres' pressure is the cellulose completely hydrolyzed and changed into hydro-cellulose, $C_{12}H_{22}O_{11}$. A red coloration of the paper with phloroglucin and hydrochloric acid, the author considers to be due to sugar and to be no indication of the presence of incrusting substances. Wood yields, when boiled with distilled water in open vessels, considerable quantities of soluble matters. The solvent power of water increases notably with increasing pressure, and reaches its maximum at five atmospheres pressure. Above five atmospheres it diminishes again. Under the most favorable conditions, 26·75 per cent. was extracted from the beech-wood and 19·17 per cent. from the fir-wood. Of these amounts, 11·19 per cent. in the first case and 9·07 per cent. in the second case was saccharine material. Besides the sugar, the extracts contain dextrine-like constituents, precipitable by alcohol. From all the extracts of the wood, ether withdraws brownish products of decomposition, which give beautiful color reactions with phenols and hydrochloric acid. Neither aquenus nor ethereal liquids, nor the residues from them, show any vanillin odor or reaction for vanillin. On the contrary, these color reactions all recall Ihl's reaction with phenols and hydrochloric acid, which is obtained with the decomposition products of the carbohydrates. The author therefore concludes that they do not indicate the existence of vanillin

or coniferin in the wood-incrusting matters, but rather indicate the change of woody tissue into carbohydrates and their decomposition products.—*Dingler Polytech. Jour., 1889*, 273–276. S. P. S.

RECENT INFORMATION AS TO THE FAILURE OF THE BAKU PETROLEUM DEPOSIT.—Early in this year statements appeared in the papers as to the gradual failing of the Baku oil wells. These have been confirmed as a result of the careful exploration of the Baku district by A. M. Kouschin, a mining engineer, sent by the Russian government. He states that the Balachone-Sabuntschi naphtha occurrence forms a definite basin, with well-defined boundaries, covering a surface of about fifteen square kilometres. Its boundaries to the south and east are the lines of the out-cropping of the Aral-Caspian limestone, to the west the mud volcano Bog-Boga and its spurs, and to the north the naphtha-containing sediments are interrupted at the farms of the village Zabrat. An overstepping of this naphtha zone has proven futile. The Nobel Company, who bored to the north by Lake Zabrat, experienced absolute failure only. Other firms who bored on the western border of the Balachani district, on the southerly slopes of Bog-Boga, met the same negative results. A boring beyond the southerly or eastern border is also totally without promise, as the naphtha-containing sediments here would be overlaid by such a thick covering of limestone as to make a penetration impossible. So the territory is perfectly defined.

Just as the Balachone-Sabuntschi naphtha zone has a well-defined superficial area, so it is found to have a definite depth, which has been settled by the borings of 1888–89 to be for Balachone, 200 to 300 metres; for Sabuntschi, 300 to 400 metres, and for Romanow, 400 to 600 metres. Below this depth, one strikes a rock which is destitute of light naphtha. The important question, then, is what quantity of naphtha has nature accumulated in this Balachone-Sabuntschi-Romanow basin? The solution of this question carries with it the decision as to when the naphtha of Baku will be exhausted. The Engineer Kouschin, on the occasion of conference with the producers at Baku, estimated that the original quantity held in this basin was four and a half milliards of poods (one pood = 16.4 kilograms). Reckoning the output to date as one milliard poods, there is left three and a half milliard poods. This, Kouschin considers, will last seventeen and a half years, with an annual production of 200,000,000 poods. In case the annual production is pushed, it will come to an end in correspondingly shorter time. The project of a naphtha pipe-line he considers to be entirely impracticable, as the returns for seventeen years would not be sufficient to cover the cost.

The failure of the wells at Balachone, where the deposits lie nearest the surface, and where the strongest oil fountains were found, and the absence of strong pressure at Sabuntschi, where the production is now centred, has produced a crisis in the Baku refining industries and the price of crude naphtha has risen to five kopecs per pood, the highest price for years. At the same time, the price of the stock of the Nobel Company has fallen in the St. Petersburg Stock Exchange. S. P. S.

Correspondence of the Chemiker Zeitung, Sept. 4, 1889.

ON THE PHYSIOLOGY OF TANNIN. From a monograph, *Grundlinien zu einer Physiologie des Gerbstoffs*, von Gregor Kraus. Leipzig, 1889. See also *Journal of the Chemical Society* for September, 1889.—The author describes twenty-one series of experiments, which comprise some hundreds of tannin determinations.

These include the estimation of the amount of tannin in leaves under the various conditions of light, shade and darkness, which lead the author to conclude that light and carbon dioxide are essential agents in the formation of tannin in leaves.

The outer leaves of a plant, exposed to direct sunlight, contain more tannin than the inner leaves.

Leaves which are not green are not capable of producing tannin.

It must not be assumed that tannin is a product of the assimilation of chlorophyll grains, as there are innumerable leaves which assimilate tannin without producing tannin; the oak, willow and alder assimilate in dull weather without increasing in tannin.

The tannin produced in the leaves passes into the branches and roots, and there is no experimental evidence that the tannin which has once passed into the rhizome undergoes further change; there is rather an increase in the amount of tannin in the rhizome through a production in the dark.

The author is inclined to believe the use of tannin to leaves is to protect them, either from being eaten, or to prevent rotting, etc.

Fallen leaves contain as much tannin as they did during their best time of growth, indicating that the leaf tannin is of no value to the plant. During the germination, in the dark, of seeds containing tannin (as oak and horse-chestnut) there is no diminution, but an increase in the amount of tannin. There is not yet sufficient evidence to show whether tannin is produced from non-nitrogenous substances, or whether it is formed in the conversion of nitrogenous compounds into albuminoids. It seems probable that aromatic compounds may be formed in the production of albumen, some of which are used in the building up of albumen molecules, while others yield tannin. H. T.

ON THE DETERMINATION OF THE BOILING POINT OF OZONE AND THE FREEZING POINT OF ETHYLENE. BY K. OLSZEWSKI (*Ann. Phys. Chim.*, 2, **37**, 337, through *Jour. Chem. Soc.*, **56**, 821).—Hautefeuille and Chappuis have shown that ozonized oxygen solidifies to a dark blue liquid at a pressure of 125 atmospheres, and at the temperature at which ethylene evaporates under the atmospheric pressure, namely, $-102.5°$ C., the ozone remains in a liquid state after the pressure has been reduced to that of the atmosphere, from which it follows that the boiling point of ozone cannot be very much lower than that of ethylene, and, therefore, the author hoped to be able to obtain liquid ozone by injecting ozonized oxygen into a vessel cooled to $-150°$ C. at the ordinary atmospheric pressure. He found, however, that he was unable to do this. The vessel was cooled down to $-151°$ C. by means of liquid ethylene, but no ozone was liquefied, being evidently prevented from doing so by the large quantity of oxygen with which it was mixed, the boiling point of oxygen

being very much lower. By using liquid oxygen at the atmospheric pressure in place of ethylene, the temperature was reduced to $-181{\cdot}4°$, and the ozone was then easily obtained in the form of a dark-blue liquid, whilst the oxygen with which it was mixed remained uncondensed and was allowed to escape by an opening at the top of the tube. When the ozonized oxygen was injected into a tube thus surrounded by liquid oxygen at the temperature of $181{\cdot}4°$, a drop of ozone could be observed in the course of a few minutes, and if the influx of gas was then stopped and the oxygen surrounding the tube allowed to evaporate, the ozone remained liquid until the whole of the oxygen had evaporated. It was necessary in performing this experiment to cut off the supply of ozonized oxygen, as when this was not done the liquid ozone was swept out of the tube by the stream of gas. After the oxygen had completely evaporated, the temperature of the tube would be about $-150°$, namely, that of the liquid ethylene surrounding the tube which originally contained the liquid oxygen.

At the boiling point of oxygen the ozone remained in the form of a dark-blue liquid, which was transparent in thin layers, but became almost opaque at a thickness of 2 mm.

In order to determine the boiling point of the ozone, the tube containing it was removed from the apparatus and placed in another vessel containing liquid ethylene at a temperature of $-140°$. The ozone was found to remain liquid until the ethylene had nearly reached its boiling point. The temperature at which the ozone began to evaporate was observed by means of a sulphurous acid thermometer, which was found to register $-109°$, corresponding to $-106°$ of the hydrogen thermometer, so that the boiling point of pure ozone may be taken as $-106°$.

The greatest care had to be exercised in making the experiments to prevent ozone from coming in contact with the ethylene, which would cause it to explode. In one of the experiments a drop of liquid ozone, just below its boiling point, exploded in this way, and the explosion was so violent that the triple glass walls of the apparatus were blown into fine dust.

When the ozone was allowed to evaporate it changed into a bluish colored gas which retained its color at the ordinary temperature, and could be recondensed by immersing it in liquid ethylene.

In a former paper, the author has described his attempts to freeze ethylene by allowing it to evaporate in a vacuum. His attempts, however, were unsuccessful, the ethylene remaining liquid and transparent at a temperature of $-162°$, and a pressure of between one and two millimetres of mercury.

He has now succeeded in solidifying ethylene by enclosing it in a tube surrounded by liquid oxygen, itself surrounded by liquid ethylene, as in the case of the experiments with ozone. The ethylene was found to solidify at about the boiling point of oxygen $-181{\cdot}4°$, to a white, crystalline, semi-transparent mass.

When the stopcock, through which the oxygen, as it evaporated, was allowed to escape, was closed so as to allow the pressure and the temperature of the oxygen gradually to increase, the solid ethylene became liquid at

a pressure of 3·4 atmospheres, at which, according to the author's former research, the temperature of the liquid oxygen would be —169°, which may, therefore, be taken as the melting point of solid ethylene. W. H. G.

BOOK NOTICES.

THERMODYNAMICS OF THE STEAM-ENGINE AND OTHER HEAT-ENGINES. By Prof. Cecil H. Peabody. New York: John Wiley & Sons. 1889. pp. xviii, 470.

Most writers on the steam engine, from a thermodynamic standpoint, determine what would take place in a steam-cylinder if certain conditions were fulfilled, the result being that but little attention is paid to what actually does occur there. The present work, after deducing the general equations of thermodynamics, brings together in a convenient shape many of the reliable experiments that have been made on the steam-engine, so that, as far as our present knowledge extends, the action of steam under different conditions can be studied.

Chapters I to V contain a statement of the first and second laws of thermodynamics and a deduction of the fundamental equations. The discussion of these equations, as applied to perfect gases, completes the sixth chapter. Chapter VII treats of saturated vapor, and gives in a small space an application of the fundamental equation to steam and incidentally to a number of other vapors. The next chapter treats of the thermodynamics of superheated steam. The flow of liquids and the application to injectors is next treated of, the results of experiments with a Sellers, Hancock, Lombard and a Dodge injector being given. Chapter XI treats of hot-air engines, and is descriptive rather than analytical, and gives something of a general idea of the method of handling the problems arising. The subject of gas-engines is barely touched upon.

Chapters XII to XIX are devoted to the steam-engine. The apparatus and methods for conducting tests are given and numerous examples from all sources are given from the experiments of the Naval Engineers on the Michigan, in 1861, to the test of a Worthington pumping engine, by Professor Unwin, in 1888. The apparatus used and the precautions taken are given in many cases. The entire subject is presented in such a way that the data and results can readily be compared and studied.

One chapter treats of the friction of steam-engines, showing what part of the entire friction of the engine is chargeable to any moving part.

Chapters XX treats of compressed air-engines, blowers, etc., and the last chapter deals with refrigerating machines.

The entire work is the best on the subject that has lately been issued, and should be in the possession of everyone studying the action of steam in an engine.

An odd mistake is made on page 183, where the text for that page is omitted and the corresponding page from Whitham's Steam-Engine Design is inserted in its stead. H. W. S.

A Manual of Machine Construction for Engineers, Draughtsmen and Mechanics. By John Richards. Philadelphia: J. B. Lippincott Company. 1889. pp. 153.

The scope of this work is best given by a summary of the general heads under which the work is arranged. Machine design is treated generally, and then particularly as to sections of machine frames, rib and plate sections, fly-wheel rims, spokes and struts, machine columns and standards, bosses for screws, nuts and foundation bolts, bearings for shafts and spindles and sliding bearings. Section second treats of the transmission of power, driving by belts and ropes, hydraulic, steam, air, gas and electrical transmission. Section third deals with steam machinery and covers the details of valves, ports, engine-frames, crank shafts and pins, connecting-rods, cross-heads and matters connected with steam-boilers. Section fourth treats of hydraulics, water-wheels, pumps, pipes and fittings. Section fifth, of mechanical drawing, heat, dynamics and the properties of materials. The last section treats of weights and measures and gives various tables, such as circumferences and areas of circles, square and cube roots, etc.

It will be seen that the ground covered by the work is quite extensive, and it is surprising that it has generally been so well worked out.

The matter treated of is of the character that comes before everyone engaged in designing machinery, and the book is filled with exactly the details that are wanted.

For instance, take the subject of collars for shafts. The author first states that cast-iron is not a suitable material for solid collars and forged ones are expensive. A sketch is then given of a malleable cast-iron or steel collar, and a table of all the dimensions for different sized shafts is given. The table is followed by remarks in the nature of cautions as to the use of this design. Most of the other subjects are treated in practically the same way.

As long as the author deals with proportions of the details of machinery the advantages of his long engineering training renders that portion of the work very valuable to the designer. When he goes outside of that the work becomes indefinite, and in some cases misleading. For instance, what could be less clear than the following, on indicated and actual horse-power, pp. 77, 78:

"*Indicated horse-power*.—This term is employed to define the pressure exerted by the pistons of engines, and is the mean pressure multiplied by the area of the piston in inches and by the velocity in feet per minute. This gives foot-pounds, that is, pounds raised one foot high in a minute; 33,000 of these foot-pounds are estimated at one horse-power, so that dividing by this number gives indicated horse-power.

"*Actual horse-power*.—From the indicated power of an engine, there must

be deducted certain losses by friction in the engine, friction of transmitting machinery, clearance at the ends of the cylinder and leaks," etc.

That the term indicated horse-power is employed to define pressure exerted by the piston of an engine is new; that foot-pounds mean pounds raised one foot high *in a minute* is not so; and that clearance and leaks are responsible for any of the difference between indicated and actual horse-power is rather surprising.

Again, on the subject of locomotive slide-valves, p. 82, a valve is given with certain data, and the following statement is made: "Steam follows sixty-four per cent. of the stroke. Exhausts at eighty-five per cent. Compression, 0·6 per cent. This applies to the forward stroke." Then, this peculiar statement: "The back stroke will vary as the length of the connecting rods."

Under the head of dynamics (p. 134) we find: "Power is a resultant of force and velocity. Work is a resultant of force, velocity and time. If either force or velocity are changed, power is changed accordingly. If either force, velocity, or space are changed, work is changed in the same proportion."

Definitions of power and work could hardly be put more awkwardly and still be correct.

The form in which the book is gotten up makes it somewhat more convenient than is usually the case with works of this kind. The pages are 6¾ x 10½ inches, bound along the shorter side, which is the top of all the printed pages. Every other page is blank for notes—a most excellent feature. The pages are numbered at the bottom and on both corners, facilitating use. There is no index beyond the table of contents, but as this is quite full very little trouble is required to find any subject.

It is doubtful whether what may be called the general information contained in the work will be of any value to anyone, but as a work of reference for the actual details of machine construction it will be of great assistance to the draughtsman and engineer. H. W. S.

STEAM-ENGINE DESIGN. By Prof. Jay M. Whitham. New York: John Wiley & Sons. 1889. pp. ix, 391.

In the preface, the author states that the work treats of the application of mechanics to the designs of the parts of a steam-engine of any type, or for any duty. While he has given himself a large field to work in, he has covered the constructive details very well. The examples given of the different parts of the engine are from the latest practice. Giving the results obtained by the different methods of treatment adds greatly to the value of the work.

Thus in the early part of the work, under the head of piston, six different methods of building up pistons are given, from the small ones with sprung ring to the largest marine piston. Numerous examples of packing pistons and of setting out the packing are given.

Empirical and analytical methods are given, where possible, for the design of the parts of the steam-engine and the results obtained are usually placed together for comparison. Thus three methods give for the thickness of the piston taken as an example, 4·76, 5·45 and 5·43 inches.

The designs of all the parts of the engine are treated in much the same way, empirical rules being given, and where rational analytical methods can be applied formulæ are deduced and the results then compared with those of actual practice.

Perhaps this can be best illustrated by the design of compound-engine cylinders, as given on page 155. Six methods of deducing the diameters of the cylinders are given, and their results are followed by the actual sizes of the cylinders used. As the engine, if the cylinder were made according to some of the sizes deduced, would cost considerably less than as actually built, it would be interesting to know which method to select if one wishes to design a compound-engine. This is the only defect in the work. Numerous examples or methods of working are given, but the advantages of one method over another, or of one plan of fitting up a part over another, are not dwelt upon to any extent. Ordinarily, the results would vary quite an amount, so that it would often be a serious question in the cost of an engine as to whether one size, or method, rather than another, should be used.

The work, as a whole, cannot fail to be of very great service to designers and draughtsmen, as it brings together many of the methods of working out details, but, as a reference book, it should have been condensed into one-fourth the size.

The work is to be commended for the superior quality of the figures, as much care has evidently been taken in their preparation, and clearer or handsomer ones are seldom found. H. W. S.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Alumni Association, Philadelphia College of Pharmacy. Twenty-fifth Annual Report. From the Secretary of the Association.

American Iron and Steel Association:
Tariff Miscellany for 1889.
Tariff Tract No. 1. 1889. From the Association.

Brown & Sharpe Manufacturing Company:
Catalogue of the Library.
Catalogues and Price-Lists. From the Company.

Clark, A. Arnold. Discussion of Diseases Incident to Poverty.
Discussion of the Subject of School Hygiene.
Germ Army.
Money Value of Sanitary Work.
Nuisances.
Relation of the English Language to other Languages.
From the Author.

Dickson Manufacturing Company. Illustrated Catalogues of Boilers, Hoisting Engines, Locomotives, Machinery for the Transmission of Power. From the Company.

Digestive Ferments. From Parke, Davis & Co.

Dujardin-Beaumetz. Clinical Therapeutics. From Parke, Davis & Co.

Electrical Bureau, Philadelphia. Annual Report. From the Chief of the Bureau.

Elgin Telephone and Electrical Supply Company. Catalogue. From the Company.

Eyerman, John. Mineralogy of Pennsylvania. Part 1.
Notes on Geology and Mineralogy.
On the Mineralogy of the French Creek Mines.
From the Author.

Grier, John A. Our Silver Coinage. From the Author.

Houston, E. J. Dictionary of Electrical Words, Terms and Phrases. From the Author.

Hutchinson, J. C. About Gloves. From the Author.

Johnson Railroad Signal Company. Catalogue. From the Company.

Keokuk, Iowa, Board of Health. Third Annual Report. From the Physician to the Board.

Knowlton's Bathing Apparatus. Pamphlets. From E. J. Knowlton.

Lawes & Gilbert:
Lawes, J. B. History of a Field Newly Laid Down to Permanent Grass.
Gilbert, J. H. Results of Experiments at Rothamsted on the Growth of Potatoes. From the Authors.

Lawes, J. Bennet. Memoranda of the Origin, Plan, and Results of the Field and Other Experiments Conducted on the Farm and in the Laboratory at Rothamsted. 1889. From the Author.

LeHardy, J. C. Rational Method of Preventing Yellow Fever on the South Atlantic Coast. From the Author.

Lewis, Henry Carvill. Sketch. From Edward S. Sayers.

Lick Observatory. Reports on the Observations of the Total Eclipse of the Sun of January 1, 1889. From the Observatory.

Lingle's College. Announcement. From the Principal.

Maine State Board of Health. Fourth Annual Report. From the Secretary of the Board.

Maritime Canal Company, of Nicaragua.

Nicaragua, the Gateway to the Pacific. From the Company.

Maryland Bureau of Industrial Statistics and Information. First Biennial Report. From Dr. Isaac Norris, Jr.

Meteorological Office, London. Weekly Weather Review, May 13 to September 2, 1889. From the Office.

Michigan State Board of Health. Seven Pamphlets. From the Board.

Morse, Willard H. New Therapeutical Agents. From Parke, Davis & Co.

New Jersey. Agricultural Experiment Station. Eighth and Ninth Annual Reports.
- Asylum for the Insane. Thirteenth Annual Report.
- Jahresbotschaft Seiner Excellenz Robert S. Green. 1889.
- Commissioners of the Sinking Fund. Annual Reports. 1887–1888.
- Annual Report of the Attorney-General. 1888.
- Board of Commissioners of Pilotage. Annual Report. 1888.
- State Board of Pharmacy. Annual Report. 1888.
- Acts of the One Hundred and Eleventh and One Hundred and Twelfth Legislatures.
- Minutes of Votes and Proceedings. One Hundred and Eleventh and One Hundred and Twelfth General Assembly.
- Journal of the Forty-third and Forty-fourth Senate.
- Secretary of State as Commissioner of Insurance. Annual Report. 1887–1888.
- Quartermaster-General. Annual Report. 1887–1888.
- Erziehungs Rath. Jahresbericht. 1888.
- Treasurer's Account. Report of Joint Committee. 1888.
- State Geologist. Annual Report. 1888.
- Staats Geologen. Jahresbericht. 1888.
- Riparian Commissioners. Annual Report. 1888.
- State Board of Assessors. Fourth and Fifth Annual Reports.
- Inspector of Factories and Workshops. Sixth Annual Report 1888.

New Jersey. Inspector der Fabriken und Werkstætten. Sechster Jahresbericht. 1888.
Board of Health. Twelfth Annual Report.
State Board of Agriculture. Fifteenth Annual Report.
Staats Ackerbau Rathes. Fünfzehnter Jahresbericht.
Bureau of Statistics. Tenth Annual Report.
Dairy Commissioner. Report. 1887–1888.
Adjutant-General. Report. 1888.
Banks and Savings Institutions. Annual Statement. 1887–1888.
State Lunatic Asylum. Annual Report. 1888.
From the State Historical Society.

Nipher, Francis E. Report on Missouri Rainfall.
Winding of Dynamo Fields.
From the Missouri State Weather Service.

Ohio Agricultural Experiment Station. Seventh Annual Report.
From the Station.

Oldham, Joshua. Catalogue and History of Saws. From the Author.

Page Belting Company. Telegraph Cipher Code and Catalogue.
From the Company.

Pelton Water Wheel Company. Descriptive Pamphlets.
From the Company.

Pennsylvania. Internal Affairs. Annual Report of the Secretary. Part 3. 1887. From the Secretary.
State College Agricultural Experiment Station. Bulletin No. 8.
From the Station.

Pope, F. L. Evolution of the Incandescent Electric Lamp.
From the Author.

Portable Copying Press and Stationery Company. Descriptive Catalogue, Price List and Samples. From the Company.

Pratt & Letchworth. Illustrated Catalogue Malleable Iron and Carriage Hardware.
Buffalo Harness.
Buffalo Indestructible Toys.
Buffalo Steel Castings.
From Pratt & Letchworth.

Printers' Circular. Vol. 23. From W. C. Bleloch, Publisher.

Quimby, Watson Fell. Solomon's Seal. From the Author.

Ramapo Iron Works. Car Truck and Track Equipment.
From the Works.

Reed, R. Harvey. Chemical Observations on some of the Effects of Direct and Indirect Traumatisms of the Brain.
Heating and Ventilation of the Mansfield Schools and Churches.
Sanitary Inspection of Passenger Coaches.
From the Author.

Richmond and Danville Railroad Company. Catalogue of the Minerals and Woods of the Regions Traversed by the Lines of the Company.
From the Company.

Rogers, Charles C. Intelligence Report of the Panama Canal.
From the Navy Department.

Rogers, Henry Raymond. Lectures on Gravity and Nebular Hypothesis.
From the Author.

Royal Irish Academy. Todd Lecture Series. Vol. 1. Part 1 and Vol. 2. Transactions. Vol. 29. Parts 3 to 11. From the Academy.

Rumsey Manufacturing Company. Catalogues Nos. 29, 40 and 45.
From the Company.

Simplex Electrical Company. Tables of Wires. From the Company.

Society of Engineers. London. Transactions for 1888.
From the Society.

Staver and Walker Catalogues. From Staver & Walker.

Tanite Company. Illustrated Pamphlets. From the Company.

U. S. Commissioner of Labor. Fourth Annual Report.
From the Commissioner.

U. S. Department of Agriculture:
Album of Agricultural Statistics of the U. S.
Division of Entomology. Bulletin, September, 1889.
Experiment Station. Bulletin No. 2.
Report of the Statistician. No. 66.
From the Department.

U. S. Department of the Interior. Twenty-six volumes of Congressional Documents. From the Department.

U. S. Department of State. Reports from the Consuls. July, 1889.
From the Department.

U. S. Hydrographic Office:
Pilot Chart, North Atlantic Ocean. September and October, 1889.
Publications. No. 90.
St. Thomas, Hatteras, Hurricane. From the Office.

U. S. Signal Office Tri-Daily Meteorological Record. From the Office.

University of Illinois. fourteenth, Report of the Trustees.
From the Regent.

University of Virginia. Announcements. Scientific and Engineering Departments. 1889–90. From the University.

University of Wisconsin. Agricultural Experiment Station. Bulletin No. 20. From the Station.

Ursinus College. Catalogue. 1888–89. From the Librarian.

Vogelsang Screw Propeller. Its Advantages.
From the Vogelsang Screw Propeller Company.

Von Mueller, Baron F. Select Extra Tropical Plants.
From Parke, Davis & Co.

Wakefield Rattan Company. Illustrated Catalogue and Price List. 1890.
From the Company.

Waltham, Mass. Water Department. Eleventh to Sixteenth Annual Reports for 1883 to 1888. From the Department.

Warner Observatory. Rochester. History and Work. Vol. 1. From the Observatory.

Warren, B. H. The Birds of Pennsylvania. From J. C. Delaney, Librarian of the Senate of Pennsylvania.

Waterbury, Conn. Board of Water Commissioners. Seventeenth to Twenty-second Annual Reports for 1883 to 1888. From the Board.

Whipple, Fred. H. The Electric Railway. From the Author.

Whitaker. Reference Catalogue of Current Literature. 1875, 1880 and 1885. From Henry C. Baird & Co.

White's Photographic Specialties Catalogue. From Otis C. White.

Whittingham Automatic Switch Description. From the Automatic Switch Company.

Wier, C. B. de. The Teacher's Standard Piano Method. From the Author.

Wisconsin Railroad Commissioner. Third Biennial Report. From the Commissioner.

Wisconsin State Board of Health. Twelfth Report. From the Secretary.

Wisconsin State Historical Society. First Triennial Catalogue of the Portrait Gallery. From the Society.

Woodbury, Merrill, Patten and Woodbury Air Engine Company. Prospectus, description and test. From the Company.

Woodbury Engine Company. Descriptive Pamphlets. From the Company.

Yale and Towne Manufacturing Company. A Key to Good Locks. From the Company.

Yale University. Report for the year 1888-89. Presented by the Board of Managers of the Observatory. From the Secretary of the Board.

Zoölogical Society, Philadelphia. Seventeenth Annual Report. From the Society.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, October 16, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
WEDNESDAY, October 16, 1889.

Dr. ISAAC NORRIS, in the Chair.

Present, 162 members and thirty-four visitors.

The Actuary's report exhibited six additions to membership since the previous meeting.

The Secretary reported the following resignations from the Committee on Science and the Arts, viz: Profs. Wm. H. Greene and L. B. Hall, and Messrs. J. R. McFetridge, Alex. E. Outerbridge, Jr., and J. Rodman Wharton.

An election to fill the vacancies resulted in the choice of—

Mr. N. H. Edgerton	for the unexpired term		of	Prof. Greene.
Dr. Chas. B. Dudley	"	"	"	Prof. Hall.
Mr. Thos. P. Conrad	"	"	"	Mr. Wharton.
Mr. Wm. H. Thorne	"	"	"	Mr. Outerbridge.
Mr. Addison Hutton	"	"	"	Mr. McFetridge.

Mr. ALEX. CRAWFORD CHENOWETH, of New York, engineer in charge of the new aqueduct for the city of New York, gave a description of the more important engineering features of this work. The speaker illustrated his subject with the aid of numerous lantern views.

Mr. JULES JUVENET read a paper on "Ramie," with especial reference to the introduction of the culture of this valuable fibre plant into the United States. He gave an account, also, of machinery and processes of his invention for the preparation of the fibre of the plant for use in the textile industries. (Referred for publication.)

The Secretary's Report embraced a description of an improved "car starter," invented by Mr. J. H. Palmer, of Philadelphia, and an account of the process of M. Adolphe Minet, for the production of aluminium by the electrolysis of its fluorides.

Adjourned.

WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW
For SEPTEMBER, 1889.

Prepared under the Direction of the Committee on Meteorology of the Franklin Institute.

Hall of the Franklin Institute,
Philadelphia, September 30, 1889.

TEMPERATURE.

The mean temperature for the month of September, 1889, deduced from the reports of fifty stations, was 61°·9, which is about one degree above the normal, and two degrees above that of September, 1888. The greatest departures were in the southeastern part of the State. The means of the daily maximum and minimum temperatures were 70°·8 and 53°·0, respectively, making a daily mean of 61°·9, and an average daily range of 17°·8.

The highest temperatures recorded were Columbus, 92°; Lebanon, 91°; Petersburg, 90°; Greenville, 90°; New Castle, 90°, and Pittsburgh, 90°.

The lowest were Pillipsburg, 30°; Clarion, 31°; Petersburg, 31°; New Castle, 31°; Coudersport, 31°; Columbus, 31°, and Dyberry, 31°.

The highest temperatures occurred on the 1st and 2d, and the lowest on the 23d.

Frosts were general on the 23d.

Stations with the highest monthly averages were Myerstown, 68°·7; Philadelphia, 66°·4; Pottstown, 65°·0, and Uniontown, 64°·9.

The lowest averages were Dyberry, 57°·2; South Eaton, 57°·5; Phillipsburg, 57°·7; Eagles Mere, 58°·2, and Wellsboro, 58°·4.

BAROMETER.

The average pressure, 30·04, is slightly below the normal. The lowest occurred on the 20th and 21st. The range for the State was about one inch.

PRECIPITATION.

The average precipitation for the State, 5·05 inches, is an excess of 1·50 inches. The greatest departures were in the eastern part of the State, where

the following totals in inches were reported: Kennett Square, 10·01; West Chester, 9·95; Eagles Mere, 9·35; Coatesville, 9·12; Forks of Neshaminy, 8·76, and Doylestown, 8·61. The smallest totals were Wellsboro, 2·71; Altoona, 2·74; Grampian Hills, 2·76; Emporium, 2·84, and Somerset, 2·94. The heavy rains, from the 10th to the 15th, did not extend to the extreme western part of the State. A few stations reported light snow on the 19th, 20th and 21st.

NOTE.—Observers are particularly requested to enter the time of the beginning and ending of precipitation. Also to note *excessive precipitation.*

Excessive precipitation is an actual fall of 2·50 inches or over in twenty-four hours, or one inch or more in one hour.

WIND AND WEATHER.

The notable West Indian hurricane, which occasioned the destructive floods along the seaboard of New Jersey from the 9th to the 12th, caused high winds and heavy rains throughout the eastern and middle portions of Pennsylvania. The whole month may be characterized as wet and unpleasant. The dampness caused considerable delay in wheat seeding, and rotted potatoes so badly that only a very small crop was secured.

Average Number.—Rainy days, 13; clear days, 8; fair days, 8; cloudy days, 14.

Prevailing Direction of Wind.—West.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Pittsburgh, 3d, 4th; Blue Knob, 3d, 16th; Quakertown, 17th; State College, 16th; West Chester, 6th, 15th, 16th, 17th, 19th; Coatesville, 14th, 16th, 17th; Rimersburg, 3d, 4th; Catawissa, 15th, 16th; Uniontown, 3d, 4th; Petersburg, 16th; Indiana, 4th; New Castle, 11th; Myerstown, 6th, 16th; Annville, 16th; New Bloomfield, 15th, 16th; Philadelphia, 16th, 17th; Girardville, 16th; Selins Grove, 16th; Somerset, 6th, 16th; Canonsburg, 10th; York, 16th; Lancaster, 16th; Wilkes-Barre, 16th; Kennett Square, 16th.

Frost.—Blue Knob, 18th, 23d, 28th; Hollidaysburg, 23d; Le Roy, 22d, 27th; Quakertown, 23d; Emporium, 23d; Phillipsburg, 23d; West Chester, 23d, 28th; Coatesville, 23d; Rimersburg, 23d; Grampian Hills, 23d; Catawissa, 23d; Harrisburg, 23d; Uniontown, 23d, 28th; Petersburg, 23d; New Castle, 23d; Myerstown, 23d, 24th, 27th, 29th; Greenville, 28th; Philadelphia 23d; Girardville, 20th, 26th; Selins Grove, 23d; Somerset, 18th, 23d, 28th; Eagles Mere, 23d, 28th, 29th; Wellsboro, 23d, 28th; Columbus, 23d; Canonsburg, 23d; Dyberry, 23d, 29th; Honesdale, 23d, 29th; York, 23d, 29th; Lancaster, 23d, 27th; Wilkes-Barre, 23d; South Eaton, 23d.

Hail.—Blue Knob, 21st; Quakertown, 21st; Bethlehem, 19th, 21st; Philadelphia, 1st; Girardville, 19th; Selins Grove, 21st.

her Service for September, 1889.

	Precipitation.		Number of Days.			Wind. Prevailing Direction.			Observers.
	Total Inches.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
Al	2·87	11	9	9	12	N	N	NE	Oscar D. Stewart, Sgt. Sig. Corp
Bg	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Rev. A. Thos. G. Apple.
Bc.	7·08	10	9	5	16	NW	NW	NE	C. M. Dechant, C.E.
BB	2·74	12	. . .	. . .	. . .	. . .	. . .	. . .	Dr. Charles B. Dudley.
Bl.	4·70	18	5	5	20	NW	NW	NW	A. H. Boyle.
Bl.	3·01	15	10	10	10	W	W	W	Prof. J. A. Stewart.
Bö	3·21	12	7	4	19	SE	SE	SE	Charles Beecher.
Br	3·13	12	7	8	15	SW	SW	SW	Geo. W. T. Warburton.
Br.	8·76	8	9	8	13	NE	W	W	J. C. Hilsman.
Bu.	8·06	15	6	10	14	NE	NE	NW	J. L. Heacock.
C4	4·59	9	. . .	. . .	. . .	. . .	. . .	. . .	E. C. Lorentz.
Ca	2·84	9	5	14	11	W	W	E	T. B. Lloyd
Ce	3·67	14	5	7	18	W	SW	W	Prof. Wm. Frear.
Ce	2·91	16	3	7	20	SW	SW	SW	Geo. H. Dunkle.
Ch	9·95	18	11	7	12	N	NW	NW	Jesse C. Green, D.D.S.
Ch	9·12	17	12	3	15	W	S	W	W. T. Gordon.
Cb	10·01	17	9	6	15	N	N	S	Benj. P. Kirk.
Cl	. . .	10	7	12	11	E	W	E	Rev. W. W. Deatrick, A.M.
Cl	3·32	5	13	6	11	NE	SW	SW	C. M. Thomas, B.S.
Cl	2·76	14	4	8	18	W	W	W	Nathan Moore.
Cl	4·73	15	9	5	16	W	W	W	Prof. John A. Robb.
Co	4·47	11	. . .	. . .	. . .	. . .	. . .	. . .	Robert M. Graham.
Cr	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	R. B. Derickson.
Cu	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	J. E. Pague.
Da	4·53	17	8	7	15	W	W	W	Frank Ridgway, Sgt. Sig. Corps.
De	8·04	11	1	12	17	NW	SE	SW	Prof. Susan J. Cunningham.
Er	4·85	15	10	9	11	S	S	S	Peter Wood, Sgt. Sig. Corps.
Fa	3·79	11	12	11	7	NW	SE	E	Wm. Hunt.
Fo	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	R. L. Haslet.
Fr	4·13	8	. . .	. . .	. . .	. . .	. . .	. . .	Miss Mary A. Ricker.
Fu	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Thomas F. Sloan.
Ht	4·53	9	11	9	10	W	W	W	Prof. W. J. Swigart.
Ht	3·57	11	6	10	14	W	S	W	J. E. Rooney.
In	4·06	17	5	16	9	NE	NE	N	Prof. S C. Schmucker.
La	6·38	15	5	12	13	SE	W	W	E. E. Weller.
La	4·01	10	8	12	10	SE	SE	SE	Wm. T. Butz.
Le	3·45	15	8	5	17	E	E	E	Wm. H. Kline.
Le	. . .	. . .	4	8	18	NW	NW	NW	Geo. W. Bowman, A.M., Ph.D.
Lu	5·56	17	. . .	. . .	. . .	. . .	. . .	. . .	H. D. Miller, M.D.
Lu	5·79	13	5	4	15	NW	NW	NW	A. W. Betterly.
Me	3·68	12	8	7	15	SE	SE	NE	Prof. S. H. Miller.
Mc	8·44	9	11	7	12	NE	NE	NE	Charles Moore, D.D.S.
No	6·14	17	14	2	14	W	W	W	Lerch & Rice.
Pe	5·02	16	7	6	17	E	E	E	Frank Mortimer.
Ph	4·66	17	7	6	17	NE	NE	NE	Luther M. Dey, Sgt. Sig. Corps.
Po	2·90	6	8	8	14	W	W	W	C. L. Peck.
Sc	6·50	17	8	1	21	W	NW	W	E. C Wagner.
Sn	5·16	10	4	10	6	SW	SE	SE	J. M. Boyer,
So	2·94	10	10	11	9	NW	NW	NW	W. M. Schrock.
Su	9·35	14	8	7	15	SW	SW	SW	E. S. Chase.
Ti	2·71	14	6	10	14	N	N	N	H. D. Deming.
W	5·25	11	10	9	11	SW	SW	SW	Wm. Loveland.
W	3·41	11	10	10	10	SE	NE	SE	A. L. Runion.
W	4·18	12	5	9	16	NW	NW	NW	Theodore Day.
W	5·90	18	. . .	. . .	. . .	. . .	. . .	. . .	John Torrey.
W	3·32	11	6	4	17	N	N	N	Benj. M. Hall.
Yo	6·87	13	13	3	14	NW	NW	NW	Mrs. L. H. Grenewald.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for September, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer.			Temperature.												Relative Humidity.	Dew Point.	Precipitation.		Number of Days.			Wind. Prevailing Direction.			Observers.
			Mean.	Highest.	Lowest.	Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Date.	Least.	Date.			Total Inches.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
Allegheny,[1]	Pittsburgh,	847	30·028	30·244	29·495	65·6	90·0	1	44·0	23	73·6	57·5	16·1	29·0	...	6·0	...	73·3	54·9	2·87	11	9	9	12	N	N	NE	Oscar D. Stewart, Sgt. Sig. Corps.
Bedford,	Charlesville,	1,300	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Rev. A. Thos. G. Apple.
Berks,[1]	Reading,	304	30·056	30·279	29·636	63·5	84·0	2, 16	42·0	22, 27	73·0	54·1	18·9	34·0	2	8·0	12	89·2	63·8	7·08	10	9	5	16	NW	NW	NE	C. M. Dechant, C.E.
Blair,[2]	Altoona,	1,181	...	...	...	64·4	86·0	6	41·0	23	72·5	56·2	16·3	26·0	1	5·0	15	...	...	2·74	12	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Blue Knob,	2,100	...	...	...	60·0	86·0	5	38·0	21	65·8	55·4	10·4	18·0	1	6·0	21	...	...	4·70	18	5	5	20	NW	NW	NW	A. H. Boyle.
Blair,	Hollidaysburg,	947	...	...	...	62·0	87·0	1, 3	32·0	23	73·6	50·8	22·8	40·0	23	11·0	13	84·7	57·6	3·01	15	10	10	10	W	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718	30·049	30·327	29·494	60·2	86·0	3	32·5	23	70·2	50·2	20·0	35·5	3	8·0	17	84·3	55·1	3·21	12	7	4	19	SE	SE	SE	Charles Beecher.
Bradford,	Le Roy,	875	...	...	...	59·8	84·0	4	37·0	27	67·3	52·9	14·4	25·0	23	5·0	21	...	...	3·13	12	7	8	15	SW	SW	SW	Geo. W. T. Warburton.
Bucks,	Forks of Neshaminy,	...	...	...	...	61·9	82·0	6	48·0	23, 29	...	...	...	...	...	...	...	...	...	8·76	8	9	8	13	NE	W	W	J. C. Hilsman.
Bucks,	Quakertown,	536	30·040	30·320	29·510	61·6	84·0	6	36·7	23	72·2	53·5	18·7	34·2	3	4·3	12	86·4	57·4	8·06	15	6	10	14	NE	NE	NW	J. L. Heacock.
Cambria,	Johnstown,	1,184	...	...	...	62·8	85·0	1, 3	42·0	27, 29	71·3	54·3	17·0	30·0	29	10·0	17	...	...	4·59	9	...	...	...	...	...	...	E. C. Lorentz.
Cameron,	Emporium,	1,030	...	...	...	62·9	84·0	3, 4	35·0	23	71·4	50·5	20·9	34·0	29	8·0	17	...	...	2·84	9	5	14	11	W	W	E	T. B. Lloyd
Centre,	State College— Agricultural Experiment Station,	1,191	30·023	30·298	29·454	60·6	81·0	1, 3	36·0	23	68·3	51·7	16·6	31·0	23	7·0	17	76·2	54·2	3·67	14	5	7	18	W	SW	W	Prof. Wm. Frear.
Centre,	Phillipsburg,	1,350	...	...	...	57·7	85·0	3	30·0	23	69·7	49·8	19·9	40·0	23	7·0	17	...	...	2·91	16	3	7	20	SW	SW	SW	Geo. H. Dunkle.
Chester,	West Chester,	455	30·029	30·314	29·515	62·6	84·0	6	42·0	23	70·7	56·6	14·1	25·0	29	4·0	12	81·0	56·5	9·95	18	11	7	12	N	NW	NW	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	62·9	88·0	6	37·0	23	73·5	57·4	16·1	36·0	23	4·0	12	...	...	9·12	17	12	3	15	W	S	W	W. T. Gordon.
Chester,[1]	Kennett Square,	275	...	...	...	62·8	...	...	...	...	...	...	...	...	...	...	...	...	...	10·01	17	9	6	15	N	N	S	Benj. P. Kirk.
Clarion,	Rimersburg,	1,500	...	...	...	61·9	87·0	1	40·0	28	68·6	56·0	12·6	24·0	23	1·0	20	...	...	...	10	7	12	11	E	W	E	Rev. W. W. Deatrick, A.M.
Clarion,	Clarion— State Normal School,	1,530	...	...	...	61·8	86·5	1	31·0	23	69·7	50·7	19·0	45·0	1	3·0	21	79·6	55·3	3·32	5	13	6	11	NE	SW	SW	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	...	...	...	60·4	86·0	1	32·0	23	68·8	54·0	14·8	29·0	3	6·0	20	...	...	2·76	14	4	8	18	W	W	W	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	62·9	87·0	1	36·0	23	72·1	53·0	19·1	39·0	23	7·0	17	...	...	4·73	15	9	5	16	W	W	W	Prof. John A. Robb.
Columbia,	Catawissa,	491	...	...	...	63·3	80·5	1, 16	39·0	23	...	...	...	...	...	...	...	...	...	4·47	11	...	...	...	...	...	...	Robert M. Graham.
Crawford,	Meadville— Allegheny College,	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. B. Derickson.
Cumberland,	Carlisle,	480	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Pague.
Dauphin,[1]	Harrisburg,	361	30·068	30·322	29·559	62·6	82·0	16	43·8	23	70·3	57·3	13·0	25·0	23	4·0	12	80·6	56·2	4·53	17	8	7	15	W	W	W	Frank Ridgway, Sgt. Sig. Corps.
Delaware,	Swarthmore— Swarthmore College,	190	30·023	30·383	29·615	63·8	85·0	6	41·0	23	72·1	56·4	15·7	29·5	23	3·5	12	82·6	58·6	8·04	11	1	12	17	NW	SE	SW	Prof. Susan J. Cunningham.
Erie,[1]	Erie,	681	30·032	30·265	29·466	63·0	85·0	2, 15	42·0	23	69·0	56·0	13·0	25·0	29	3·0	16	76·0	54·0	4·85	15	10	9	11	S	S	S	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	30·000	30·177	27·039	64·9	89·0	1	38·0	23	73·3	55·4	17·9	34·0	23	6·0	6	79·4	58·5	3·79	11	12	11	7	NW	SE	E	Wm. Hunt.
Forrest,	Tionesta,	1,057	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. L. Haslet.
Franklin,[1]	Chambersburg— Wilson Female College,	618	30·009	30·339	29·597	62·9	86·0	15, 17	34·0	23	71·6	54·2	17·4	35·0	23	6·0	12	86·1	57·5	4·13	8	...	...	...	...	...	...	Miss Mary A. Ricker.
Fulton,	McConnellsburg,	875	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Thomas F. Sloan.
Huntingdon,[1]	Huntingdon— The Normal College,	650	...	...	...	62·6	87·2	1	35·0	23	76·5	53·9	22·6	38·0	26	9·0	25	...	...	4·53	9	11	9	10	W	W	W	Prof. W. J. Swigart.
Huntingdon,	Petersburg,	700	...	...	...	61·1	90·0	1	31·0	24	71·1	52·5	18·6	37·0	3	3·0	6	...	...	3·57	11	6	10	14	W	S	W	J. E. Rooney.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	61·7	87·6	1	35·0	23	71·1	50·6	20·5	36·7	28	10·0	14	81·3	55·9	4·06	17	5	16	9	NE	NE	N	Prof. S. C. Schmucker.
Lancaster,	Lancaster,	413	30·023	30·197	29·621	62·8	87·0	4	39·0	23	71·9	54·7	17·2	38·0	4	6·0	12	90·9	60·5	6·38	15	5	12	13	SE	W	W	E. E. Weller.
Lawrence,	New Castle,	932	...	...	...	63·1	90·0	1, 2	31·0	23	74·1	50·1	24·0	40·0	23	7·0	20	...	...	4·01	10	8	12	10	SE	SE	SE	Wm. T. Butz.
Lebanon,	Myerstown,	474	30·017	30·261	29·531	61·9	87·9	9	36·5	23	72·7	54·4	18·3	34·5	23	5·1	12	87·7	57·3	3·45	15	8	5	17	E	E	E	Wm. H. Kline.
Lebanon,	Annville— Lebanon Valley College,	339	...	...	...	68·7	91·0	9	50·0	29	...	...	...	...	...	...	...	80·8	63·5	...	...	4	8	18	NW	NW	NW	Geo. W. Bowman, A.M., Ph.D.
Luzerne,	Drifton— Drifton Hospital,	1,655	...	...	...	58·9	78·0	15	40·0	22, 23	67·2	52·7	14·5	28·0	3	7·0	12	...	...	5·56	17	...	...	...	...	...	...	H. D. Miller, M.D.
Luzerne,[1]	Wilkes-Barre (24 days),	575	...	...	...	60·5	82·0	16	37·0	23	67·0	54·0	13·0	32·0	23	3·0	12	...	...	5·79	13	5	4	15	NW	NW	NW	A. W. Betterly.
Mercer,[1]	Greenville— Thiel College,	1,000	30·030	30·262	29·426	59·3	90·3	2	33·8	23	73·1	55·3	17·8	37·4	7	5·7	30	92·5	56·5	3·68	12	8	7	15	SE	SE	NE	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	...	...	...	65·0	88·0	6	41·0	23	73·0	58·0	15·0	29·0	23	3·0	12	84·0	60·0	8·44	9	11	7	12	NE	NE	NE	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	...	...	...	64·0	83·0	6	40·0	29	72·0	56·0	16·0	30·0	2	8·0	12	80·0	58·0	6·14	17	14	2	14	W	W	W	Lerch & Rice.
Perry,	New Bloomfield,	400	...	...	...	61·3	88·0	1	34·0	23	72·0	54·0	18·0	39·0	23	3·0	17	...	...	5·02	16	7	6	17	E	E	E	Frank Mortimer.
Philadelphia,[1]	Philadelphia,	117	30·046	30·330	29·330	66·4	87·0	6	47·0	22	73·4	59·5	13·9	22·0	23	4·0	12	80·0	60·0	4·66	17	7	6	17	NE	NE	NE	Luther M. Dey, Sgt. Sig. Corps.
Potter,	Coudersport,	1,670	...	...	...	60·5	88·0	30	31·0	23	69·7	47·2	22·5	33·0	4	4·0	20	90·0	56·5	2·90	6	8	8	14	W	W	W	C. L. Peck.
Schuylkill,	Girardville,	1,000	30·066	30·318	29·631	61·3	80·0	16	37·0	23	69·0	52·5	16·5	28·0	29	8·0	11	...	...	6·50	17	8	1	21	W	NW	W	E. C. Wagner.
Snyder,	Selins Grove,	445	...	...	...	63·1	84·0	3	41·0	23	73·6	33·0	40·6	59·0	1	28·0	20	79·0	58·0	5·16	10	4	10	6	SW	SE	SE	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	57·0	88·0	1	32·0	23	69·9	50·0	19·9	34·0	23	7·0	24	83·0	54·0	2·94	10	10	11	9	NW	NW	NW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	30·102	30·438	29·568	58·2	74·0	16	36·0	23	63·8	50·5	13·3	22·0	23	3·0	19	80·7	51·8	9·35	14	8	7	15	SW	SW	SW	E. S. Chase.
Tioga,	Wellsboro,	1,327	30·024	30·325	29·439	58·4	88·0	4	30·0	23	69·9	51·1	18·8	18·0	1	2·0	4	69·2	48·3	2·71	14	6	10	14	N	N	N	H. D. Deming.
Warren,	Columbus,	1,410	...	...	...	61·0	92·0	1, 2	31·0	23	72·2	49·8	22·4	46·0	1	2·0	16	83·1	53·2	5·25	11	10	9	11	SW	SW	SW	Wm. Loveland.
Washington,	Canonsburg,	950	...	...	...	62·5	88·0	1, 2	36·0	22	73·0	52·0	21·0	40·0	23	16·0	30	73·0	55·0	3·41	11	10	10	10	SE	NE	SE	A. L. Runion.
Wayne,	Dyberry,	1,100	...	...	...	57·2	82·0	16	31·0	29	68·4	48·7	19·7	36·0	3	5·0	12	...	...	4·18	12	5	9	16	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	60·1	80·0	16	34·0	23	68·0	55·2	12·8	28·0	23	5·0	12	76·0	58·0	5·90	18	...	...	...	...	...	...	John Torrey.
Wyoming,[1]	South Eaton (27 days),	660	...	...	...	57·5	80·1	5	32·0	23	65·2	49·8	15·4	31·8	23	3·0	13	...	...	3·32	11	6	4	17	N	N	N	Benj. M. Hall.
York,[1]	York,	385	30·056	30·340	29·603	63·4	85·0	4	38·5	23	73·4	55·5	17·9	38·5	23	5·0	12	78·3	57·7	6·87	13	13	3	14	NW	NW	NW	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

Erie.	New Castle.	Greenville.	Columbus.	Pittsburgh.	West Chester.	Coatesville.	Kennett Square.	Dyberry.	Honesdale.	Quakertown.	Swarthmore.	Philadelphia.	Seisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Nesham'y.	Germantown.	Point Pleasant.	Bethlehem.
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·12	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·15	·11	·07	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·73	·28	·17	·20	·15	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·07	. .	·14	·58	·07	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·91	1·03	·62	1·08	1·33	·35	·01	·19	·55	·69	·41	·81	·01	·08	·20	·04	. .	. .	·01	·17	·36	. .	·41
. .	. .	. .	. .	. .	·23	. .	. .	·26	·24	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·02
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·52	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	·83	·65	·30	. .	·04	·37	·50	·24	. .	. .	. .	. .	. .	. .	. .	. .	. .	·37
. .	. .	. .	. .	. .	·72	·58	·58	. .	·13	·44	·81	·24	. .	·36	·41	·63	. .	. .	. .	. .	·64	·49
. .	. .	. .	. .	. .	1·01	·91	·83	1·31	1·62	·65	·37	·36	. .	. .	·57	. .	. .	. .	. .	. .	. .	·83
. .	. .	. .	. .	. .	·87	·62	·72	·10	·04	·78	·80	·65	. .	. .	·53	. .	. .	. .	. .	2·44	. .	·50
. .	. .	. .	. .	. .	1·12	·80	1·82	·14	·10	·16	. .	·03	1·73	1·00	·02	2·11	3·00	2·30	3·17	. .	2·10	·12
. .	. .	. .	. .	. .	·32	·13	·75	·08	·08	·18	. .	·02	. .	·16	1·00	. .	·44	·70	. .	. .	. .	·39
·95	·35	·96	·64	·20	·10	·03	·28	. .	1·52	. .	1·12	·93	1·66	·41	·94	1·83	. .	. .	1·87	. .	1·85	·61
·31	·45	·41	·35	·55	1·60	3·13	1·53	·72	·35	3·40	2·15	·76	. .	1·37	1·89	·43	. .	. .	. .	. .	·41	2·09
·41	. .	·06	·55	. .	·47	·45	·59	·45	·32	·39	·46	·40	2·74	2·09	·10	1·64	3·00	2·90	2·22	1·64	1·62	·08
·26	. .	·06	·66	·03	·13	·10	. .	·11	·13	·14	·07	·02	·22	·03	·22	·26	·45	·40	·01	·05	·25	·01
·78	·65	·40	·87	·21	·16	·18	·08	·22	·30	·11	. .	·04	. .	·14	·10	·11	·16	·23	·23	·11	·10	·04
·05	·11	·27	·07	·01	·07	·04	·07	·08	·05	·02	·07	·01	·20	. .	·04	·05	·40	·50	·05	. .	·07	·08
·01	. .	. .	. .	. .	. .	. .	. .	. .	·04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	·36	·43	·23	. .	. .	·35	. .	·18	. .	. .	·70	. .	. .	. .	. .	. .	. .	·04
. .	·10	. .	. .	. .	1·48	·99	1·97	. .	·14	·52	·88	·67	. .	. .	·20	. .	. .	. .	. .	. .	. .	·03
·08	·05	·09	·08	·05	·11	·05	·05	·16	·07	·14	. .	·07	·69	·83	·02	1·01	1·16	1·18	1·04	·96	1·10	·03
·01	. .	. .	. .	·02	. .	. .	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
·01	·88	·43	·17	·25	·02	. .	·01	. .	·04	. .	. .	·03	. .	. .	·08	. .	. .	·10	. .	. .	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
4·85	4·01	3·68	5·25	2·87	9·95	9·12	10·01	4·18	5·90	8·06	8·04	4·66	7·32	6·68	7·38	8·07	8·61	8·32	8·76	5·56	8·14	6·14

T. F. T

PRECIPITATION FOR SEPTEMBER, 1889.

Day	Erie.	New Castle.	Greenville.	Columbus.	Pittsburgh.	Uniontown.	Clarion.	Indiana.	Johnstown.	Somerset.
1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
2	·12	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	·15	·11	·07	. .	. .	·07	. .	·18	·92	. .
4	·73	·28	·17	·20	·15	·56	·24	·22	. .	. .
5	·07	. .	·14	·58	·07	. .	. .	·01	. .	. .
6	·91	1·03	·62	1·08	1·33	·84	1·18	1·75	. .	·41
7	. .	. .	. .	. .	. .	. .	. .	. .	. .	·10
8	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
9	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
10	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
11	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
12	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
13	. .	. .	. .	. .	. .	. .	. .	·01	. .	·04
14	. .	. .	. .	. .	. .	. .	. .	. .	. .	·08
15	. .	. .	. .	. .	. .	. .	. .	·02	1·18	·48
16	·95	·35	·96	·64	·20	·45	·20	·37	·37	·66
17	·31	·45	·41	·35	·55	·95	. .	·28	1·28	·63
18	·41	. .	·06	·55	. .	. .	. .	·81	. .	. .
19	·26	. .	·06	·66	·03	·03	. .	·25	·30	·18
20	·78	·65	·40	·87	·21	·24	. .	·37	·33	·18
21	·05	·11	·27	·07	·01	. .	. .	·06	·01	. .
22	·01	. .	. .	. .	. .	. .	. .	·01	. .	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	. .	. .	. .	. .	·23	. .	·01	·04	·18
25	. .	·10	. .	. .	. .	. .	1·20	. .	. .	. .
26	·08	·05	·09	·08	·05	·20	. .	·03	. .	. .
27	·01	. .	. .	. .	·02	·03	. .	·07	. .	. .
28	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
29	. .	. .	. .	. .	. .	. .	·50	. .	·16	. .
30	·01	·88	·43	·17	·25	·19	. .	·15	. .	. .
31	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Total	4·85	4·01	3·68	5·25	2·87	3·79	3·32	4·60	4·59	2·94

Day	Grampian Hills	Emporium.	Blue Knob.	Phillipsburg.	Petersburg.	Huntingdon.	Hollidaysburg.	Altoona.	Chambersburg.
1	. .	. .	. .	. .	. .	. .	. .	. .	. .
2	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	. .	. .	. .	. .	. .	. .	. .	. .	. .
4	. .	. .	. .	. .	. .	. .	. .	. .	. .
5	·05	. .	. .	. .	. .	. .	. .	. .	. .
6	·50	·73	·20	·20	·38	. .	·25	·12	. .
7	·11	. .	·20	·40	·41	1·03	·34	·05	1·20
8	. .	. .	·10	. .	·02	·27	. .	·13	1·10
9	. .	. .	. .	. .	. .	. .	. .	. .	. .
10	. .	. .	. .	. .	. .	. .	. .	. .	. .
11	. .	. .	. .	. .	. .	. .	. .	. .	. .
12	·10	·15	·10	. .	·03	. .	·08	. .	. .
13	·06	. .	. .	·15	·30	·25	·33	·22	. .
14	·04	·08	·40	·16	·12	. .	·17	·15	. .
15	·25	·12	·20	·15	·07	·25	·04	. .	·05
16	·12	·21	·30	·02	·04	1·50	·38	·07	. .
17	·72	·63	1·00	·70	1·90	·85	·86	1·10	·45
18	. .	. .	·20	·59	. .	·20	·17	·68	·28
19	·08	. .	·20	·08	. .	. .	. .	. .	. .
20	·10	·15	·30	·01	·01	·10	·07	·04	·05
21	·44	·10	·90	·19	. .	. .	·09	·06	. .
22	. .	. .	·10	·15	. .	. .	. .	·04	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	. .	. .	. .	·01	. .	·05	. .	·90
25	. .	. .	·10	·01	. .	. .	. .	. .	·10
26	·04	. .	·10	·01	·14	. .	·06	. .	. .
27	. .	. .	. .	·01	. .	. .	·01	. .	. .
28	. .	. .	. .	. .	. .	. .	. .	. .	. .
29	. .	. .	. .	. .	. .	. .	. .	. .	. .
30	·15	·67	·30	·08	·14	·08	·11	·08	. .
31	. .	. .	. .	. .	. .	. .	. .	. .	. .
Total	2·76	2·84	4·70	2·91	3·57	4·53	3·01	2·74	4·13

Day	State College.	York.	Lock Haven.	New Bloomfield.	Wellsboro.	Harrisburg.	Selins Grove.	Lancaster.	Le Roy.
1	. .	. .	. .	. .	. .	. .	. .	. .	. .
2	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	. .	. .	. .	. .	. .	. .	. .	. .	. .
4	. .	. .	. .	. .	. .	. .	. .	. .	. .
5	. .	. .	. .	. .	. .	. .	. .	. .	. .
6	·22	·30	·25	·32	·16	·16	·40	·49	·31
7	·53	·50	·49	1·40	1·08	·70	·69	·24	·24
8	·02	. .	·27	·03	. .	·02	. .	. .	·02
9	. .	. .	. .	. .	. .	. .	. .	. .	. .
10	. .	·01	. .	. .	. .	. .	·01	. .	. .
11	. .	·45	. .	·10	. .	·12	·02	·18	. .
12	·27	·50	·50	·82	·08	·26	·50	·23	·10
13	·31	·56	·29	·44	·10	·30	·03	·33	·34
14	·26	·33	·65	·71	·08	·36	·15	·20	·05
15	·01	·09	·02	·11	·02	·09	·12	·09	. .
16	·44	. .	·05	·05	·10	·80	1·00	·08	. .
17	·72	2·40	·82	·31	·74	·60	1·19	2·68	1·17
18	·41	·90	·60	·30	·10	·26	·51	·44	·52
19	. .	. .	·02	. .	·05	. .	. .	. .	·06
20	·26	·03	·27	·13	·10	·09	·14	·09	·09
21	·07	. .	·14	. .	. .	·05	. .	. .	·14
22	. .	. .	. .	. .	. .	. .	. .	. .	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	·45	. .	·18	. .	·54	·05	·68	. .
25	. .	·35	. .	·04	. .	·08	·08	·60	. .
26	·06	. .	·11	·04	·06	·08	·12	03	·09
27	. .	. .	. .	. .	. .	. .	. .	. .	. .
28	. .	. .	. .	. .	. .	. .	. .	. .	. .
29	·09	. .	. .	. .	. .	. .	. .	. .	. .
30	. .	. .	·25	·04	·04	·02	·15	·02	. .
31	. .	. .	. .	. .	. .	. .	. .	. .	. .
Total	3·67	6·87	4·73	5·02	2·71	4·53	5·16	6·38	3·13

Day	Eagles Mere.	Myerstown.	Wysox.	Catawissa.	Girardville.	Wilkes-Barre.	South Eaton.	Drifton.	Reading.
1	. .	. .	. .	. .	. .	. .	. .	. .	. .
2	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	. .	. .	. .	. .	. .	. .	. .	. .	. .
4	. .	. .	. .	. .	. .	. .	. .	. .	. .
5	. .	. .	. .	. .	. .	. .	. .	. .	·95
6	·65	·54	·52	·28	·79	1·10	. .	1·96	·95
7	1·01	·21	·14	·60	·57	. .	·41	·35	·04
8	. .	. .	. .	. .	. .	. .	. .	. .	. .
9	. .	. .	. .	. .	. .	. .	. .	. .	. .
10	. .	·01	. .	. .	. .	. .	. .	. .	·02
11	. .	. .	. .	·12	·23	·24	·04	·10	·13
12	1·10	·51	·48	·62	1·03	·72	·81	·33	·17
13	·42	·41	·06	·02	·72	1·20	·12	·14	·25
14	·35	·08	. .	·23	·44	·04	·15	·32	·41
15	1·10	·15	. .	. .	·32	. .	. .	·10	·93
16	·33	·07	·20	1·20	·66	·61	. .	·68	. .
17	·45	·80	1·20	·92	·69	·61	·87	·18	1·96
18	·35	·32	. .	. .	·14	·63	·50	·41	·53
19	. .	·03	·16	. .	·19	. .	·04	·19	. .
20	·42	·03	·22	·27	·18	·27	. .	·06	·04
21	. .	·02	·04	. .	·03	·15	·14	·26	. .
22	. .	. .	. .	. .	. .	. .	. .	·05	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	. .	. .	. .	·10	. .	. .	. .	·36
25	·85	·23	. .	·15	·09	·10	·05	·18	·29
26	1·10	·02	·04	·06	·12	·10	·19	·20	·05
27	. .	. .	. .	. .	. .	. .	. .	. .	. .
28	. .	. .	. .	. .	. .	. .	. .	. .	. .
29	. .	. .	·01	. .	. .	. .	. .	. .	. .
30	1·22	·02	·14	. .	·20	·02	. .	·05	. .
31	. .	. .	. .	. .	. .	. .	. .	. .	. .
Total	9·35	3·45	3·21	4·47	6·50	5·79	3·32	5·56	7·08

Day	Pottstown.	West Chester.	Coatesville.	Kennett Square.	Dyberry.	Honesdale.	Quakertown.	Swarthmore.	Philadelphia.	Seisholtzville.	Frederick.
1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
2	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
4	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
5	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
6	. .	·35	·01	·19	·55	·69	·41	·81	·01	·08	·20
7	. .	·23	. .	. .	·26	·24	. .	. .	. .	. .	. .
8	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
9	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
10	·40	·83	·65	·30	. .	·04	·37	·50	·24	. .	. .
11	. .	·72	·58	·58	. .	·13	·44	·81	·24	. .	·36
12	·57	1·01	·91	·83	1·31	1·62	·65	·37	·36	. .	. .
13	·50	·87	·62	·72	·10	·04	·78	·80	·65	. .	. .
14	·20	1·12	·80	1·82	·14	·10	·16	. .	·03	1·73	1·00
15	·20	·32	·13	·75	·08	·08	·18	. .	·02	. .	·16
16	. .	·10	·03	·28	. .	1·52	. .	1·12	·93	1·66	·41
17	5·40	1·60	3·13	1·53	·72	·35	3·40	2·15	·76	. .	1·37
18	·12	·47	·45	·59	·45	·32	·39	·46	·40	2·74	2·09
19	. .	·13	·10	. .	·11	·13	·14	·07	·02	·22	·03
20	. .	·16	·18	·08	·22	·30	·11	. .	·04	. .	·14
21	. .	·07	·04	·07	·08	·05	·02	·07	·01	·20	. .
22	. .	. .	. .	. .	. .	·04	. .	. .	. .	. .	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	·80	·36	·43	·23	. .	. .	·35	. .	·18	. .	. .
25	·25	1·48	·99	1·97	. .	·14	·52	·88	·67	. .	. .
26	. .	·11	·05	·05	·16	·07	·14	. .	·07	·69	·83
27	. .	. .	. .	·01	. .	. .	. .	. .	. .	. .	. .
28	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
29	. .	. .	·02	. .	. .	. .	. .	. .	. .	. .	. .
30	. .	·02	. .	·01	. .	·04	. .	. .	·03	. .	. .
31	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Total	8·44	9·95	9·12	10·01	4·18	5·90	8·06	8·04	4·66	7·32	6·68

Day	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Neshan'y.	Germantown.	Point Pleasant.	Bethlehem.	Canonsburg.
1	. .	. .	. .	. .	. .	. .	. .	. .	. .
2	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	. .	. .	. .	. .	. .	. .	. .	. .	·05
4	. .	. .	. .	. .	. .	. .	. .	. .	·15
5	. .	. .	. .	. .	. .	. .	. .	. .	·25
6	·04	. .	. .	·01	·17	·35	. .	·41	1·40
7	. .	. .	. .	. .	. .	. .	. .	·02	. .
8	. .	. .	. .	. .	. .	. .	. .	. .	. .
9	·52	. .	. .	. .	. .	. .	. .	. .	. .
10	. .	. .	. .	. .	. .	. .	. .	·37	. .
11	·41	·63	. .	. .	. .	. .	·64	·49	. .
12	·57	. .	. .	. .	. .	. .	. .	·33	. .
13	·53	. .	. .	. .	. .	2·44	. .	·50	. .
14	·02	2·11	3·00	2·30	3·17	. .	2·10	·12	. .
15	1·00	. .	·44	·70	. .	. .	. .	·39	. .
16	·94	1·83	. .	. .	1·87	. .	1·85	·61	·37
17	1·89	·43	. .	. .	. .	. .	·41	2·09	·55
18	·10	1·64	3·00	2·90	2·22	1·64	1·62	·08	. .
19	·22	·26	·45	·40	·01	·05	·25	·01	·03
20	·10	·11	·16	·23	·23	·11	·10	·04	·25
21	·04	·05	·40	·50	·05	. .	·07	·08	. .
22	. .	. .	. .	. .	. .	. .	. .	. .	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	·70	. .	. .	. .	. .	. .	. .	·04	·04
25	·20	. .	. .	. .	. .	. .	. .	·03	. .
26	·02	1·01	1·16	1·18	1·04	·95	1·10	·03	·06
27	. .	. .	. .	. .	. .	. .	. .	. .	. .
28	. .	. .	. .	. .	. .	. .	. .	. .	. .
29	. .	. .	. .	. .	. .	. .	. .	. .	. .
30	·08	. .	. .	·10	. .	. .	. .	. .	·26
31	. .	. .	. .	. .	. .	. .	. .	. .	. .
Total	7·38	8·07	8·61	8·32	8·76	5·55	8·14	6·14	3·41

T. F. T.

Snow.—Blue Knob, 20th, 21st; Phillipsburg, 19th; Selins Grove, 21st.

Coronæ.—Myerstown, 9th; Dyberry, 4th, 9th, 29th.

Aurora.—Blue Knob, 3d.

Solar Halos.—Le Roy, 29th; Wellsboro, 20th, 26th; Dyberry, 24th; South Eaton, 24th.

Lunar Halos.—Lock Haven, 26th; Annville, 9th; Somerset, 10th, 11th; Lancaster, 4th.

WEATHER FORECASTS.

Percentage of local verifications of weather and temperature signals as reported by displaymen for September, 1889:

Weather, 88 per cent.

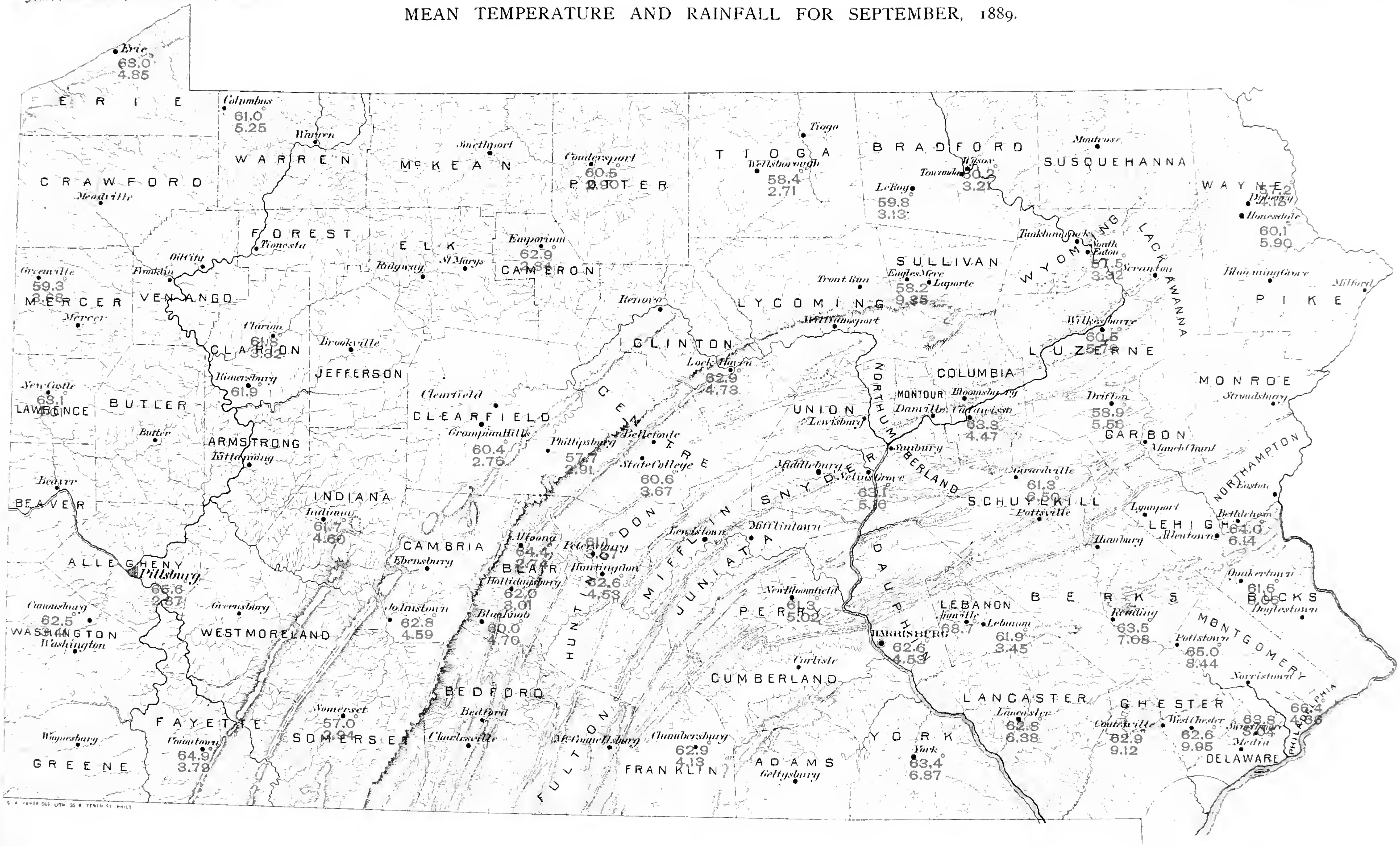
Temperature, 89 per cent.

TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

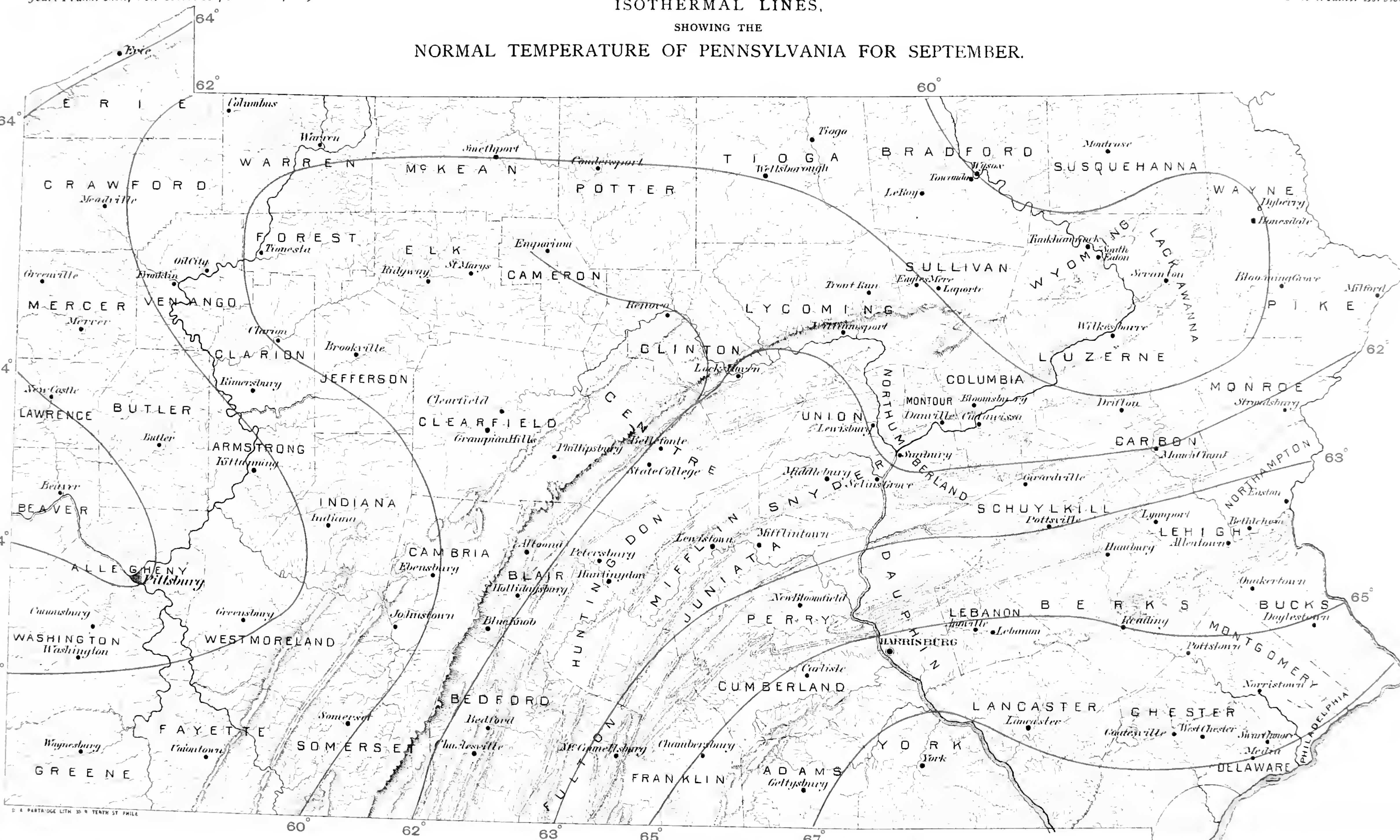
Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.

Displayman.	*Station.*
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.
W. S. Ravenscroft,	Hyndman.
R. C. Schmidt & Co.,	Belle Vernon.
Jesse R. Brown,	Lehmasters.
H. W. Mullen,	Centre Valley.
Mayer Bros.,	Bloomsburg.
E. C. Lorentz,	Johnstown.
W. M. James,	Ashland.
Miller & Allison,	Punxsutawney.
Dr. A. L. Runion,	Canonsburg.

MEAN TEMPERATURE AND RAINFALL FOR SEPTEMBER, 1889.



ISOTHERMAL LINES,
SHOWING THE
NORMAL TEMPERATURE OF PENNSYLVANIA FOR SEPTEMBER.



JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVIII. DECEMBER, 1889. No. 6.

AMERICAN ISTHMIAN CANAL ROUTES.

By DANIEL AMMEN,
Rear Admiral, United States Navy.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *November 4, 1889.*]

Admiral AMMEN was introduced by Prof. COLEMAN SELLERS, of the INSTITUTE, and spoke as follows:

MEMBERS OF THE FRANKLIN INSTITUTE AND LADIES AND GENTLEMEN:

Forty-eight years ago I was under instruction in the Naval School, in Philadelphia, which, two years later, was removed to Annapolis, and has grown into an institution worthy of the nation, aided in its infancy by the genius of Professor Chauvenet, your townsman, who instructed the midshipmen, of whom I was one.

More than a quarter of a century ago I left your port in command of the monitor *Patapsco* to take part in the bombardment of Fort Sumter. During the Civil War and after-

wards I had found many valued friends in this city. Among those I prized most highly was the late John Welsh, whose memory is so highly honored in the community, where he lived so long and usefully. In all these years I have approached Philadelphia from whatever direction with a feeling of satisfaction; there is no squalidity in its outskirts, there is none along its centres, so disagreeable a feature in neighboring cities. It seems that everybody here has a comfortable home and a useful existence, and this condition is gratifying to every one who has the instinct of humanity.

Regarding your city with so much appreciation, I was gratified to receive an invitation to deliver a lecture before this INSTITUTE, that in the past, as in the present, is recognized as one of the sources through which Philadelphia has attained such practical results in advancing the common interests of mankind, through science ministering to the necessities that belong to men. I, however, regarded the invitation rather as an acknowledgment of my efforts in obtaining information relating to the question of American Isthmian Transit than that I could be expected to say much that was not already known to the members of the INSTITUTE.

Your citizens generally know that Mr. Charles Biddle, of Philadelphia, was sent to Panama, in Central America, in May, 1835, appointed by President Jackson under a Congressional resolution that explains the earnest interest felt at that time in the consideration of an Isthmian canal and upon what political basis it should be constructed. The resolution reads as follows:

"*Resolved*, That the President of the United States be respectfully requested to consider the expediency of opening negotiations with the governments of other nations, and particularly with the governments of Central America and New Granada, for the purpose of effectually protecting, by suitable treaty stipulations with them, such individuals or companies as may undertake to open a communication between the Atlantic and Pacific Oceans by the construction of a ship canal across the isthmus which connects

North and South America; and of further securing forever, by such stipulations, the free and equal right of navigation of such canal to all nations, on the payment of such reasonable tolls as may be established to compensate the capitalists who may be engaged in such undertaking and complete the work."

In compliance with that resolution, President Jackson appointed, May 1, 1835, Mr. Charles Biddle, of Philadelphia, a special agent, to proceed to the isthmus, for the purpose of making all necessary inquiries in reference to the work. Mr. Forsyth's letter of instructions directed him to proceed by the most direct route to the port of San Juan, Nicaragua, and ascending that river, cross thence to the Pacific, making all inquiries as to plans, surveys and estimates, and procuring at Guatemala copies of all public documents regarding the subject. From Guatemala he was to proceed to Panama, make as thorough an examination as possible of the route there, and at Bogota obtain copies of public documents in reference to a projected railroad, and especially any information in relation to a concession said to have been made by the government of New Granada to a certain Baron Thierry.

Furnished with a circular letter to all the United States consuls in the countries referred to, and also in Mexico, Mr. Biddle set out on his journey, but, as it appears from the difficulties of obtaining at that time direct conveyance to San Juan, Mr. Biddle went to Panama, never reached Nicaragua, and died soon after his return to the United States, in 1836, without making any full report.

It appears, therefore, that more than half a century ago, when our territory and material interests on the west coast were prospectively insignificant as compared to their present extension and importance, our statesmen of that day, without distinction of party, regarded them sufficient to warrant the above action, and a distinguished citizen of your city was designated to carry the resolution into effect. He died fifty-three years ago, probably from his detention on the Isthmus of Panama, as pestiferous as any spot on the globe.

It is not my intention to follow this subject historically, I propose to present only a brief sketch of more recent events, relating principally to reliable surveys and their results.

The readers of *Harper's Monthly* of thirty-five years ago may recall an account of an attempted exploration of the Isthmus of Darien, by Lieut. Strain, of the Navy. It was a tragic account of loss of life through starvation in a country teeming with abundance; where one of the lords of the soil, or a hundred of them, would have set out to go from sea to sea, picking their food by the wayside. The forest would have supplied vegetable food of wholesome kinds, it was filled with game too, and the waters abounded in fish. The expedition was one of those sad adventures undertaken without study of what was necessary, not alone for success in establishing topographical facts, but as well for the prevention of misery, and the actual starvation of more than one-half of the party. After reading this narrative, I became much interested from an apparently insignificant circumstance—the supposed hearing of the evening gun of the *Cyane*, the vessel they had left three days before at anchor in Caledonia Bay. Soon after leaving the vessel to make their intended exploration, they began the ascent of a mountain, following up a ravine, and finding that toilsome, they availed themselves of a pathway of the Indians over the hills, and in the afternoon encamped on the Pacific slope. The following morning they went down this slope and soon reached a considerable stream, which they called the Sucubuti, at that point several hundred feet above the sea, as was afterwards known. An ascertainment at that time, with a level, of the height above sea of this flowing water would have effectually barred any belief in the statement that had been made by Cullen and others, as to the low line of levels between the seas higher up on the water-shed than the region they traversed. At that time, that admirable little instrument, the pocket aneroid, was not in use; with such an instrument, no more cumbersome than a watch, in one or two days the absolute falsity of the asserted low gap between the two oceans could have

been established, and further exploration on that line or above on that line of drainage, would have been entirely useless; there could be no low gap between the two seas, as asserted, with a considerable stream lying close to the coast range of mountains, hundreds of feet above the seas.

I wrote to Strain, whom I knew well, calling his attention to the significance of the supposition that they had heard the evening gun of the *Cyane*. Were it so, in my belief, a gap in the mountains would be found through which the sound had come. Months passed before I heard from him; he was then on the Isthmus of Panama, where, not long after, in 1857, he died. He made no reply to my direct question as to hearing the evening gun and expressed the belief that the Isthmus of Darien would furnish no practicable route, which he thought would be found on the Isthmus of Panama, on or near the line of the railroad. Not long after, I was ordered to the *Saranac* and made a cruise in the Pacific; on our arrival at Panama, I was transferred to the flag-ship *Merrimac*, and still interested in the Isthmus, made provisional arrangements to visit in a tug the River Chepo, the mouth of which is some twenty miles east of the city of Panama. The captain of the *Merrimac* did not approve of my personal efforts to explore, and consequently was not willing to grant me leave of absence for a week. My research would have looked to a possible connection with the Gulf of San Blas by means of a tunnel, after locking above the sea level, high enough at least to have a dry foot in making the excavation. This route has yet the unreasoning support of some well-meaning men, who can look only at one side of a question, and cannot consider relative advantages. Even should a sea-level canal be regarded there as practicable, with a tunnel certainly of not less than seven miles in length, and with a mountain overhead of some 5,000 feet in height, such a canal could not compare favorably with the Nicaragua route as now located.

On my return to the United States in the *Merrimac*, in February, 1860, I wrote to the Geographical Society of New York my ideas touching the exploration of the Isthmus, and the method that seemed to me necessary to secure satis-

factory topographical results, namely: to follow up all of the large water-sheds and make a skeleton map, with curves of elevations. These could be readily connected where desired, by lines of levels. These ideas were favorably received by the Society, but we were then absorbed in questions that terminated a few months later in civil war, which for years shut out of the public mind any consideration of Isthmian explorations.

During the early part of 1866, General Grant was on duty in Washington; he and myself had been playmates when children, which sometimes establishes an intimacy and confidence such as nothing else does. I called his attention to how little was known in relation to the Isthmus of Darien proper, where it seemed to me there was a fair prospect of finding favorable conditions for the construction of a canal. He quite agreed with me, and made an examination of an enlargement from an old Spanish map in the Naval Observatory Library. About this time Justice Field, of the Supreme Court, presented to Senator Conness, of California, a resolution, which he offered, calling upon the Superintendent of the Naval Observatory for all information touching Isthmian surveys. The passage of this resolution produced (Senate Ex. Doc. No. 62, 39th Congress, 1st Session, published in 1866) the first compendium of information relating to this subject known to me.

In the autumn of 1867, I was in command of the flagship *Piscataqua*, bound for the Asiatic station. In December, just before sailing from New York, my duties called me to Washington for a day. On leaving, General Grant took me to the station, and expressed his regret that he had thus far not been able to bring about an exploration of the Isthmus. I replied that I did not feel in any degree uneasy as to that, and had no doubt that ere long he would be able to effect it. During the following winter, Senator Conness secured an appropriation for the exploration of the Isthmus, and the subsequent election of General Grant to the Presidency enabled him to have me ordered home, his object being to send me to the Isthmus. Before reaching home, however, other officers had been assigned to two large sur-

veying parties, and I was made chief of a bureau in the Navy Department, and directed to confer with the Secretary of the Navy in relation to the Isthmian surveys then in progress.

In compliance with a resolution of Congress, on the 15th of March, 1872, the President appointed a Commission, consisting of Gen. A. A. Humphreys, Chief of Army Engineers; Capt. C. P. Patterson, Superintendent of Coast Survey, and myself, then Chief of Bureau of Navigation. Our duties were to examine into the entire Isthmian question, make suggestions as to further surveys, etc. The formulation of the orders to the officers engaged in making the surveys was placed in our hands, and we kept the President, who was deeply interested in the results, advised of the progress of the work. After the completion of the Tehuantepec, the Nicaragua and the Atrato-Napipi routes, and the several tentative lines in the vicinity of Caledonia Bay, and lying between it and the water-shed falling into the river Atrato, in South America, the Commission asked for and obtained an inspection of the Nicaragua and Atrato-Napipi routes, which seemed to promise possible practicable canal routes. Major MacFarland and Captain Heuer, of the Engineer Corps of the Army, were assigned to inspect these routes, and Mr. Mitchell, of the Coast Survey, was also ordered. General Ammen was invited, and went in an honorary capacity at the request of General Humphreys, his classmate and friend at the Military Academy, and Mr. Walton, C. E., of Louisiana, also went in an honorary capacity.

In returning, *via* Panama, General Ammen obtained such information as induced him to state to the Commission that although he thought Panama would prove greatly inferior to the Nicaragua route in first cost and still greater in maintenance, he did not see how the Commission could make a report without being subject to proper criticism, unless an instrumental examination of Panama was made and reported upon. As this would delay the completion of our report one year, I heard this opinion with a good deal of disappointment, although quite certain now that this course was a

necessity to free the Commission from possible reproach. At our request, this instrumental examination was made by the same officer in command, accompanied by the same civil engineer and medical officer who were on the Nicaragua survey. It was advantageous in every way that the relative advantages and disadvantages of the two routes should be known and passed upon by the same persons. On the completion of the Panama survey, the great inferiority of that route was shown. The necessity of making it lay in the fact that there was no authentic information obtainable otherwise than by making the survey, to enable the Commission to form an intelligent opinion as to the degree of practicability of that route. A further survey of the Atrato-Napipi route, not asked for by the Commission, established the fallacy of what had been presented as an actual instrumental line of location over a distance of about twenty miles which had not been traversed.

A satisfactory instrumental location, and calculations and plans for a canal across the Isthmus of Panama, was placed before the Commission, and soon after a final report was made, February 7, 1876. (Senate Ex. Doc. No. 15, 46th Congress, 1st Session.) It states: "That the Nicaragua route, beginning on the Atlantic side, at or near Greytown, possesses, both for the construction and maintenance of a canal, greater advantages, and offers fewer difficulties from engineering, commercial and economic points of view, than any one of the other routes shown to be practicable by surveys sufficiently in detail to enable a judgment to be formed of their relative merits, as will be briefly presented in an accompanying memorandum."

The memorandum summarizes the advantages and dis advantages of the various routes examined, from Tehuantepec, with its 754 feet of elevation and difficult, if not deficient water supply, to the Atrato-Napipi route, the farthest south. The routes examined were ten in number, of which three had plans and estimates for ship canals, based on instrumental work, the tentative examinations of the Darien and other routes being ample to show their impracticability.

From the time of the report of the Commission until the expiration of the term of President Grant, there was great political commotion in Congress, and after the Presidential election in November, there was great uncertainty as to the Presidential succession. Nothing was done looking towards the construction of the canal as recommended by the Commission; General Grant was, nevertheless, still earnest in relation to it, and, just previous to his going abroad, called on President Hayes and urged action, and asked me to remind the President of the very great importance of bringing it about under the control and auspices of our Government. The question, nevertheless, slumbered until revived by the Paris Canal Congress, May 15, 1879.

About the time that Lull had completed his surveys on the Isthmus of Panama, in 1875, a discussion was taken up in Paris by the French Section of the International Committee for the exploration of the American Isthmus. M. Drouillet, a French engineer, and the Secretary of the Committee, published a pamphlet in which he gave a synopsis of what he regarded as authorities, and he proposed methods of exploration. Notwithstanding our instrumental surveys and tentative lines over many routes, he came to the United States to make an appeal to our learned societies to lend their aid to make a general and serious exploration of the Isthmus. He asserted that "the problem of inter-oceanic navigation is, at present, incapable of solution on account of the insufficiency of geographical data, and of the flagrant contradictions which exist in these data—an insufficiency and contradictions which do not permit the engineer to study profoundly a definite project."

As a member of the Commission that had made an official report of the sufficiency of authentic information in our possession, I gave a reading before the American Geographical Society, of New York, October 21, 1876, to show that the difficulty was in M. Drouillet not being able to separate what was authentic from what was illusory. Two French expeditions were subsequently sent to the basin of the Gulf of Darien; the first year they elaborated a plan of a sea-level canal from the water-shed of the Gulf of Darien

to the Atlantic coast, with a proposed tunnel of indefinite length, and without visiting the Atlantic terminus. I discussed this route before the American Geographical Society, Nov. 12, 1878. The second year they paid a brief visit to the same region, lost several of their party through sickness, then visited the valley of the Chepo, before mentioned, and took a dozen cross-sections along the line of the Panama Railroad. From these cross-sections plans were produced for the consideration of the sea-level canal at Panama, which, on their presentation to the Paris Congress, elicited the unqualified admiration of M. de Lesseps. The history of the Congress will be found in brief in the reports of Civil Engineer Menocal and myself to the Secretary of State, published in 1879, titled "Instructions to Rear Admiral Ammen," etc. I quote from my report: "That personal interests, arising from a concession for the construction of a canal, are unfavorable to a relative consideration of natural advantages as between two or more routes; that such personal interests did exist was quite apparent from first to last; and the 'concession' was partially discussed or alluded to, especially in the committees or sub-committees."

"That the discussion in Paris has shown that hereafter in the examination of the question, only the Nicaragua and the Panama routes need critical examination, and that sufficient information exists as to all other routes."

"That a canal *a niveau* by the Isthmus of Panama, either with or without a tunnel, has been shown to be hopelessly impracticable, if considered as a commercial question, and a general and special knowledge now exists among European engineers relative to the subject of a ship canal across the American Continent, which did not exist prior to the assemblage of the Congress in Paris."

I recall the well-known fact that the ablest hydraulic engineers of the Society of Paris did not support Lesseps in his sea-level canal project, yet, of course, he had a "majority," but that did not give him a moneyed support. Failing in that, a month later, he announced that he would soon go to Panama "to see for himself," and then be able to inform the French people just what the canal would cost.

Early in December he reached Panama, accompanied by several engineers and contractors. Soon after his return to France, the "American Presidency of the Panama Canal Company," as it was styled, was offered to General Grant, with a salary of 100,000 francs. In declining the offer, the General stated that, however desirous he was of identifying himself with the construction of an inter-oceanic canal, he was not willing to do so with any project that would end in failure. Then the position was given to the "American Minister of Marine," and his acceptance trumpeted as a quasi-endorsement of the canal by our Government. The entire newspaper press of France was "subsidized," that nothing might be published that was not approved by M. de Lesseps. I have recent information that the proprietors of one of the great Parisian journals received 300,000 francs for their aid in deceiving the French people. Then the proverbial French stockings were emptied into his lap. He said a sea-level canal was demanded by the public, and he was sponsor for it.

On reaching home from the Paris Canal Congress I wrote to General Grant, who was then in Japan, urging him to take hold of the construction of the Nicaragua Canal to secure our great national interests, and received a telegram, and later a letter, that he would do so, but unhappily, soon after his arrival in Philadelphia, he was swerved from his purpose. In "Recollections of Grant," published in the *North American Review*, October, 1885, will be found something of interest as to this. Had he remained firm in his purpose there is hardly a doubt that the canal would have been completed years ago. In the same monthly, of February, 1881, will be found a long paper by him on this subject which closes as follows:

"I have formed the opinions expressed in this article not from a hasty consideration of the subject, and not without personal observation. While commanding the Army of the United States, my attention was drawn to the importance of the water communication that I have discussed. During my administration of the Government, I endeavored to impress upon the country the views I then formed, and I

shall feel that I have added one more act of my life to those I have already recorded, if I shall succeed in impressing upon Congress and the people, the high value, as a commercial and industrial enterprise, of this great work, which, if not accomplished by Americans, will undoubtedly be accomplished by some one of our rivals in power and influence."

A month before the meeting of the Paris Canal Congress, M. Blanchet, an emissary of Lesseps, returned from Nicaragua. A very favorable concession for the construction of the Nicaragua Canal was agreed upon between the executive department and himself, which failed in being confirmed by only one vote in the Senate. Soon after M. de Lesseps left Paris for Panama, in the November following the Congress, "to see for himself," information was received that M. Blanchet would soon leave for Nicaragua to make another attempt to secure the concession that had just slipped through his fingers. To forestall this, the late S. L. Phelps, who died while acting as our minister in Peru some years ago, formed a provisional association and sent an agent to Nicaragua, who arrived only two days in advance of Blanchet, and secured as favorable a concession as was desired.

No sooner were the Panama and Nicaragua Canal projects formulated than Captain Eads appeared upon the scene and proposed a ship railway across the Isthmus of Tehuantepec, and an endowment of $60,000,000 to be paid as sections were completed, in guaranteed bonds, counting the navigable parts of rivers as sections, which were nearly navigable without improvement. He had a special committee appointed for the consideration of the canal question, and actually nearly captured a majority to grant him guaranteed bonds to build his ship railway, and under this condition the supposed majority of the committee was willing to report a bill to incorporate the Nicaragua Canal without any guarantee whatever. The attempt to report the Eads bill failed, and thereafter Eads and his following, and the people in Lesseps interest, headed by the "American Syndicate," endowed with an annuity of half a million of dollars,

held watch and ward to prevent the Nicaragua bill being brought up, a very easy thing to do under the rules of the House.

To the ordinary observer of transportation, and to those conversant with navigation, if the question is regarded in a commercial sense, and the danger, if not impossibility of transporting a ship and her cargo across an elevation of 735 feet, with steep and varying grades, a distance of 150 miles, a comparison of economy with her transportation through a canal, having a satisfactory lockage of 110 feet elevation, requiring an excavated prism of less than forty miles in length, as was then known, seems absurd on its face. No ship-builder in the country endorsed his ship railway as practicable, and no insurance company expressed a willingness to take risks, yet Captain Eads had the indorsement of engineers and others who should have known better. I invited the opinions of prominent ship-builders and engineers in our country, and they were, without exception, entirely unfavorable to a ship railway. They stated in general, that a new strong ship would have her cargo taken out, or at least a considerable part of it, before being docked, and that great difficulty would be found in making a solid road-bed, and still greater in having it so level as to distribute the weights equally on the axles, failing in which they would give way. They regarded the idea as impracticable, yet Captain Eads would, in addition, subject the vessel, with a full cargo, to the percussive effect in transit, and give her a journey over hills more than 735 feet high, going at a rate of eight or ten miles an hour, with a road-bed, as his engineer said, "of at least two feet of broken stone." The ship railway required several enormous turn-tables to change direction, that had to be floated by water, and then turned and lowered again on a solid flooring, yet this ship railway was proposed "to save time and money in transit," as compared with a canal having an excavated prism of less than one-third of the length of the proposed ship railway and a lockage of less than one-sixth of its height. The late Col. John G. Stevens, and the late W. W. Evans, both engineers of world-wide reputation, wrote me their ideas that will be

found in pamphlets published by me, copies of which I have presented to the FRANKLIN INSTITUTE. At different times I exposed the impracticability of the Eads ship railway in the daily prints. I received several visits soon after, from a young gentleman who, as he informed me, was an "associate of Eads" and who was desirous that I should join the railway scheme, as it would be much more economical than a canal in the transportation of ships. I said, in reply, that this was just what I objected to, to wit: its entire lack of economy, even were it practicable; that with the experience of an old seaman I did not believe that a laden ship could be taken across on a ship railway and float on being put into the water. Nevertheless, I added, as there might be an honest difference of opinion, and as a fact, I did not wish to oppose Eads so long as his project would not be detrimental to great national interests, I had no objection to, and would not oppose any bill giving Captain Eads, *as a bonus*, just as much as the toll dues received for the transportation of all American ships carrying cargoes, having a gross weight or displacement of 2,000 tons or more, until the Captain received in full, and as a bonus, all that he asked for on guaranteed bonds. This suggestion was rejected with scorn, and confirmed me in the belief that Eads wished the Government to bear the loss of an experiment which would at least yield to him and his associates possession of a four-track railroad, very substantially built on a Government guarantee of bonds, and a line of traffic for grain and other commodities very much better situated, geographically and otherwise, than the Panama Railroad. In all this contention with Captain Eads I was not able to get him to produce a profile, yet the Eads influence embarrassed those interested in the construction of the Nicaragua Canal to the time of his death in March, 1887, covertly aided by the American Syndicate with its annuity of $500,000 "to maintain American Neutrality!" They had the adventitious aid of a pretended friend to the Nicaragua Canal Association, but an insidious foe, not to the construction of the canal, but aiding in the prevention of an act of incorporation through coveting the construction of the canal as a Government work,

and this was no less a personage than the Secretary of State.

After the expiration of the concession in September, 1884, at the invitation of the State Department, General Zavala, a former President of Nicaragua, a gentleman of great ability and character, came to Washington to negotiate a treaty looking to the construction of a canal as a Government work. Whatever influence I and some other former associates had with him was directed towards favoring the Secretary of State.

The apparent feebleness of the Association that held the Nicaragua Canal concession grew out of the fact that it was composed entirely of persons who appreciated the necessity of securing the construction of the canal in a manner not adverse to American interests. They were willing at any time to deliver over their franchises to the Government, had it been possible, or to have the work done themselves, and only asked an act of incorporation from Congress without any guarantee, until they found themselves confronted in prevention by the two great engineers, M. de Lesseps and Captain Eads. A guarantee of three per cent. was then asked, to be operative only when the canal itself was operative or doing its work for a period of twenty years. This meant only an assured protection of the canal by the Government.

However questionable the proceedings of Mr. Frelinghuysen were, and regardless of personal rights, the members of the Association would not have felt that their efforts had been in vain had they ended in the Government securing to itself the actual construction of the canal. But Mr. Frelinghuysen was not able to have the treaty confirmed. It is supposed to have been opposed by the powerful influence of the incoming Administration, and subsequently withdrawn by it, as stated at the time in the public prints, for consideration or modification. The next Congress was informed in the President's Annual Message, in December, that the treaty would not be again presented for confirmation. It was not thought worth while to ask of Nicaragua any amendments. It was supposed by our State Depart-

ment to be only worthy of being trampled under foot, but being trampled under foot by our Government would only give an undoubted advantage to the citizens of any other government to obtain a concession, and aided in any effective way by their government occupy this vantage ground to our detriment, as General Grant suggested would occur, should it be neglected by us, and this certainly would have occurred had it not been for the subsequent prompt action of citizens of the United States.

Much that I have said would have little relevancy to Isthmian transit, were it not that it shows beyond question that the impediments in the way of the construction of the Nicaragua Canal have not been of a physical nature, but vile machinations, which yet continue. In March, 1887, when Eads was expending his dying efforts in opposing the passage of an act of incorporation for the Nicaragua Canal Company, and M. Colné, the Secretary of the American Syndicate, "to maintain the neutrality of our Government" through its annuity of $500,000, was in Washington, doubtless to aid in preventing the passage of the bill, Colné gave out a telegram, received from Paris, that "M. de Lesseps would be gratified to see the Nicaragua Canal constructed; the water being fresh, would serve for irrigation, but no vessel would pass through it; they would prefer a Cape Horn voyage." It was well known to us, that for months before, the only "plan" then entertained for the construction of the Panama Canal was for a lockage of about 150 feet elevation, and for a draught of water of only about fifteen feet. Had the Panama Canal opposition ceased with this, I would have had little if anything to say of it, but it continues in one form or another, aided by influences from other quarters, the effects of which at least are apparent. A telegram from London, published in the Washington *Star*, of July 9th, states:

"Arms and money have been poured into Costa Rica, and she is in a far better condition for war than Nicaragua. It can be guessed where such opportune aid came from, and while it cannot be expected that the parties interested will openly acknowledge their implication, there is open rejoic-

ing in Paris at the promise of serious complications. A former power on the Bourse, who has been almost as completely wrecked by the collapse of the Panama Canal shares, as M. Secretan was by the copper speculation, says: 'From the inception of the Panama Canal scheme the United States has proved its most bitter and relentless enemy. By its irritating and threatening references to the ill-defined and impudent Monroe doctrine, it prevented the investment of English capital in the enterprise, and deprived it of the benefit of that English conservatism that would have so admirably supplemented French genius and secured a brilliant success for the greatest triumph of man over nature. It cannot be expected that we will sit with folded hands and see the results of our labor and expenditure rendered nugatory, as it would be by the completion of a canal through Nicaragua. We do not believe that the United States will make war upon Costa Rica for the benefit of a private company, which State would be placed in position of defending rights which, as a State, she had never surrendered.' "

I have no faith in this idea that men can "triumph over nature." It was this vain attempt, not the United States, as a bitter relentless enemy, that destroyed the Panama Canal. All that men can do, in my belief, is to study closely and execute in their interest what nature favors or permits, as we shall see Humboldt said long ago in relation to Nicaragua. Our countrymen would not believe that the United States were "making war for the benefit of a company," were it declared in the most emphatic manner, by force, if necessary, that the concessionary rights granted by both republics referred to, would be sustained and protected in the most ample manner, and, on the other hand, see to it that the canal company should fulfil all of the obligations entered into, and imposed upon it by the terms of the concessions. Any other course would leave the company open to perpetual embarrassments by European speculators, in the hope eventually of bankrupting it and getting the benefit not only of the marked physical conditions shown to exist, the results of thorough surveys, but also of all the labor and material expended up to the time of failure. The interests

of a canal company, however large, will be a mere fractional part of the great collateral interests that will grow up, even in anticipation of the completion of the canal.

A telegram from Panama, dated October 15th, announces that the *Suez Canal Company* has arranged with the government of Guatemala for the purchase of a railroad to be completed from the Atlantic to the Pacific, and to put into that country $21,312,000 in gold. As railroad men express it, this is "to parallel the Nicaragua Canal." With what has just been said, in relation to Costa Rica, my hearers will not be slow to perceive in this movement the fine hand of M. de Lesseps, the President of the Suez Canal Company. It is not unlikely that our Government may find itself compelled to repress hostilities on either side of Nicaragua, incited by the Eastern diplomacy of M. de Lesseps. The railroad in itself, passing over an exceedingly rough country at an elevation of not less than 5,000 feet, and a length not less than 300 miles, would hardly "handicap" such a work as the Nicaragua Canal; but it is plainly an indication that Suez Canal influence and money will be used to "bull" and to "bear" Nicaragua Canal stock, should it be issued upon such a financial basis as would permit it.

In looking at the construction of a canal across the Isthmus, the health question will be found the most important, even in a commercial point of view, and the humanitarian will be pleased to know that there is perhaps no country on the globe where the canal could be made, with less loss of life from disease than on the route of the Nicaragua Canal as now located. It lies between latitude 12° and 10½° north, directly in the trade wind belt and has an extreme range of temperature throughout the year of but 17°, which we all know is less than a usual daily change with us, for a large number of days in every month in the year. The general direction from Greytown to Brito is a little north of west, and the natural summit above full lake is only forty-three feet. Owing in part to the high mountains that lie at some distance on either side of the river San Juan, which is the out-

flow of the lake, a funnel-shaped entrance is given to the trade winds which traverse this district with great climatic advantage. There is a popular idea, and unhappily generally founded in fact, that human life in the tropics is ephemeral in a greater degree than in the temperate zone; that disease and death come from pestilential air; that beasts of prey pounce upon and devour the wayfarer; that deadly serpents lie in the tall weeds and thorny shrubs, that cover the ground beneath enormous trees, thickly canopied with vines and leaves, so thick that the rays of even the noon-day sun give only an obscure light.

The pestilential climate of Panama is indisputable; Puerto Bello, in the Gulf of San Blas, not far from Aspinwall, was abandoned from its extreme unhealthfulness, and the attempt of Paterson to colonize at Caledonia Bay was a failure quite as much from disease as from the fact that no practicable waterway was to be found across the Isthmus at that point, and no portage as favorable as at Panama.

That the healthfulness of Nicaragua, however, is exceptional for a tropical region, as I shall show presently, is well established as a fact.

In British India and on the Island of Singapore, statistics show an enormous loss of life through the ravages of wild beasts, and the bites of deadly serpents, amounting to tens of thousands of victims yearly. Although the jaguar and congar abound on this continent from the boundary of Texas to Patagonia, they do not attack men, and although there are venomous serpents in all inter-tropical America, they are not numerous, and are an imaginary rather than a real danger, shown from the fact that in the many surveys made by our Government, not one man has been fatally bitten, if bitten at all. The wild beasts although numerous were never seen, even in their haunts in the thick forests traversed by the surveyors. The Chief Signal officer of our Government adds another tribute to the climate of this region, from his observations: "Exempt from hurricanes and whirlwinds, owing to the constant movement of air across the Isthmus from the trade winds, although light in the rainy season." When this canal is made, as it doubt-

less soon will be, the region lying between the lakes and the Pacific will be the great sanitarium of Europe and the United States, as it will then be easy of access and will be found to fulfil the required conditions more fully than any other region known.

Seven years ago, I made the acquaintance of an English gentleman, who asked if I had read a book published in London some years before, entitled "A Naturalist in Nicaragua." I subsequently read the book with great interest and instruction. It treats of the healthfulness of the climate, even at Greytown, and the causes of it. On mentioning this to Medical Director Maccoun, of the Navy, he informed me that his personal observation at Greytown, in relation to the type of fever at that port, confirmed the statements of the writer referred to.

It was quite amenable to treatment and quite different from the "pernicious" and other deadly fevers that afflict the Isthmus of Panama. In the sitting of the Association for the Advancement of Science in the city of New York in August, 1887, Surgeon Bransford, of the Navy, gave his ideas in relation to the causes of this exceptional healthfulness of Nicaragua as compared to most inter-tropical countries. He had been the medical officer of the several expeditions sent to Nicaragua, and was competent to express an opinion in relation to the subject. He had also been on the Panama survey, and therefore able to appreciate the wide difference between the two localities. In December, 1887, sixty surveyors and assistants landed at Greytown, accompanied by 100 or more Jamaicans, and had a further accession of force of forty natives. The rainy season prevailed a month or more beyond the usual period, and during that time they were exposed in their tents and in the forests, engaged in work of an arduous nature, and this exposure continued for a period of six months without a case of serious illness in the entire party. What was remarkable, the Jamaicans were far more liable to ailment than our countrymen. This climatic difference, so well established as not to admit of dispute, if looked at only in a commercial point of view, is of immense advantage in relation to the execution of a

canal, in economy of time and money in Nicaragua, and the reverse on the Isthmus of Panama.

Sir John Hawkshaw said at the Paris Congress, in discussing the Panama Canal: "With regard to the question whether the canal should be constructed with or without locks, the following points occur to me—if the canal is to be without locks, its normal service level would be that of the sea, and its bottom level say eight metres lower. This being the case, the canal would receive and must provide for the whole drainage transversed. Therefore, it would be necessary to ascertain the volume of water that would drain into the canal before it would be possible even to determine the sectional area of the canal. If the canal have a less surface fall than the river, as it would have, it must have a larger sectional area to discharge the same volume of water. If, from such considerations as the foregoing, it should be concluded that the canal should be constructed so as to retain the rivers for natural drainage, then recourse will have to be had to locks. In that event there can be no difficulty, in my opinion, in carrying on the traffic with locks properly constructed, provided there is an ample water supply, which would be a *sine qua non*."

Sir John was regarded as able a hydraulic engineer as was known in Great Britain, and attended the Paris Canal Congress at the instance of his government. Although what he said were axioms with hydraulic engineers the world over, and his points were stated with great clearness, yet his words had no meaning for M. de Lesseps, and no endeavor to control the surface drainage of the Panama Canal has thus far been attempted. Abandoning "temporarily," M. de Lesseps said nearly three years ago, the immediate construction of a sea-level canal, his "plans" then disregarded furnishing the lock canal with a permanent water supply at the summit, and proposed pumping up thirty-three feet the deficiency. We know that in very dry seasons the Chagres River itself will furnish an inadequate water supply at 124 feet above sea, the height proposed by Lull in his plan.

In a report of Lieut. C. C. Rogers, of the Navy, recently published, there is information given out in great part from

the canal company at Panama, in March, 1887. The statements are very like reading a hopeful account of a sick patient a year or so after he has died. On page 31 is found: "It is now time to consider the dam of the Chagres at Gamboa. * * * The central line of the dam will cross the Chagres at a distance of 500 metres from the axis of the canal at the forty-fifth kilometre. The length of the dam at the base will be 300 metres; the level of its crest will be plus thirty-five metres, and the whole dam will contain 10,000,000 cubic metres of material. The geology of the Gamboa district has been studied during the past year, and it has been found that the weight of the dam when complete will be sustained by the ground beneath without need of piling or other artificial support." The Director-General assured him there will be no difficulty or expense involved outside of the dam for the successful formation of a lake whose volume would permit an accumulation of 1,000,000,000 cubic metres of water during the worst rainy season. It would seem superfluous to suggest what would happen to the canal should the basin not prove sufficient to hold all of the water "of the worst rainy season," or should that dam built "sustained by the ground beneath without need of piling or other artificial support" be swept away. A cataclysm would sweep to both seas and destroy every vessel in transit and every living being along the line of canal. But my hearers may be assured that dam will never be built. * * * On page 34 we find: "From all I could learn by conversation with the officials it does not seem that a sea level for the entire canal is a fact of the future. M. Jacquier, the Director-General, told me that a lock might be placed in the Culebra cut; and M. Charles de Lesseps remarked to me once that the canal could be finished two years sooner by building a lock at this point. The Director-General subsequently stated that if a lock were decided upon here it would be only with the agreement that at some stated time in the future the company should be allowed to remove it and excavate the cut to the depth of nine metres below the water line, thus making the canal a sea-level route for its whole length. In the present uncertainty and even doubt

as to the construction of a lock, no plans for it have been made."

Notwithstanding the difficulties that have thus far beset M. de Lesseps and his canal, his ingenuity or that of his able engineers has not been exhausted; although the dam will not be built, nor will water be pumped up thirty-three feet to the summit, it is intended that ships "shall get there all the same." I learn through a friend that M. Colné, the Secretary of the American Canal Syndicate, has just arrived from Paris, where he is supposed to have gone to confer with M. de Lesseps. He states that the canal may be constructed at the sea level, save in the deep cut of which the Culebra forms a part; there they may have a ship railway some five miles in length, or perhaps reaching to Panama Bay. *Chacun à son goût* is a French proverb, and there is no reason why M. de Lesseps should not indulge his taste.

M. de Lesseps knows now, that the "'prentice hand" of engineers may excavate at a grade of 45°; they do not "establish" it; nature then insists in putting on the finishing touches, month after month, until she is satisfied with the grade. The huge masses on the deep cut have slowly approached each other, through the effects of hydrostatic pressure and gravitation, and this would be the more pronounced the deeper the cuts were made. Fifteen years ago, the Superintendent of the Panama Railroad answered an inquiry why he had such steep grades at the summit when so little cutting would be required to lessen them, by stating, that the cut had not been deepened on account of the extreme tendency of the land to slide, and added that on one occasion a slide nipped a train on the summit and it required days to dig it out, and this had to be done by hauling up the mud in buckets. Freeing a ship stuck in the mud by a landslide would be quite a serious affair, and for years.

In the *North American Review*, of January, 1880, M. de Lesseps gave his views on the Panama Canal, in which he states: "I do not hesitate to declare that the Panama Canal will be easier to begin, to finish, and to maintain, than the

Canal of Suez." Nearly ten years later, the correspondent of the New York *Times*, September 9th, gives his observations: "For twenty-five cents of Colombian silver one may hire a small one-horse victoria, with a negro driver, to take you to the mouth of the canal at Panama. The drive is about two miles, on a road well shaded with all varieties of tropical trees, and is well worth taking, even if you do see nothing but a dirty ditch at the other end. The work at this 'show point,' so to speak, was so slovenly done that it is difficult to distinguish the lines of the canal at high water, and at low tide it has no more water than a New Jersey mud flat. Further inland, passing a few dredgers, the bed of the cut becomes a pasture for the cattle in the vicinity, and a few steps further along bring you to banana trees growing in the 'track of the future commerce of the world.' On the entire line there are now employed 100 men. They are watchmen and others who carry paint pots to paint the hundreds of rusting engines. Near the Culebra cut there must be fifty-odd fine engines, which, with their fresh coats of paint, present quite a prosperous appearance, in strong contrast to that of two years ago, when everything was going to rack and ruin through criminal neglect. The engines and the iron work I formerly saw half buried in the mud at the foot of the mountain, are now out of sight, probably to be unearthed by future generations of canal-builders, and to be regarded as evidence of the ingenuity of their ancestors as far back as the nineteenth century. How the French storekeeper accounts, even on paper, for his material, is a mystery even to an army quartermaster. Engines here on their backs and engines there on their sides may all be accounted for, even if the chaos of the Culebra cut does not remind one of the Johnstown disaster, but for the buried iron work and machines he has only one recourse—to dig down to them now, while they are not deep under ground, attach a chain to them, having on the upper or surface end an automatic-sounding buoy, to determine their position in the next overflow of the Chagres, and to continue the same plan with those that will be buried annually, as the years roll by."

We may turn with satisfaction from the wretchedly conceived and mismanaged affairs at Panama, to the ideas of the great Humboldt, who visited this continent ninety years ago. Seventy-five years ago, he wrote upon "the practicability of a water communication between the Atlantic and Pacific Oceans," to be found in his personal narrative, published in London, in 1826. I quote his words: "It would be imprudent, I here repeat, to begin at one point without having examined and levelled others; and it would be above all to be regretted if the work were undertaken on too small a scale; for in works of this description the expense does not augment in proportion to the section of the canals, or the breadth of the water channel. * * * The Isthmus of Nicaragua, by the position of its inland lake, and the communication of that lake with the Atlantic by the Rio San Juan, presents several features of resemblance with that neck of land in the Scotch Highlands, where the River Ness forms a natural communication between the mountain lakes and the Gulf of Murray. At Nicaragua, as in the Scotch Highlands, there would be but one narrow ridge to pass over; for if the River San Juan in a great part of its course is from twenty to forty feet deep, as is asserted, it would only require to be rendered navigable by means of weirs or lateral canals. * * * It appears somewhat probable that the province of Nicaragua will be fixed upon for the great work of the junction of the two oceans; and in that case it will not be necessary to form a line constantly navigable. The Isthmus to be passed over is only from four to five marine leagues; there are some hills in the narrowest part between the western bank of the Lake of Nicaragua and the Gulf of Papagayo." At the time Humboldt wrote what has been quoted, no instruments of precision, as far as known, had been used on any part of the several routes named by him as worthy of examination. It seems wonderful that the prescience of this great man should have enabled him to name not only the locality favored by nature for the construction of a ship canal, but as well the actual plan of development, analogous to the Caledonia Canal, of which he makes mention and looked upon with admiration.

The Paris Canal Congress had before it all of the information relating to the Panama route made known to us through our surveys, to which apparently little has been added of practical value by the French, and it had also all that we then knew in relation to the Nicaragua route, which was then insufficient to warrant a development analagous to the Caledonia Canal, which further examinations permitted to a greater degree of advantage than the Caledonia Canal itself. Any of my hearers can assure themselves at their leisure of this fact by a patient examination of the *Engineering News* of September 14th. The profile and plans are given in detail, and do not require an engineer to understand them; they are clearly comprehensible to any one who will take the pains to examine them carefully and read the text relating to them.

The length of transit from sea to sea is 170 miles in a north by west direction from Greytown, the Atlantic entrance; there are three locks on each side, and the elevation of the lake above sea 110 feet, as maintained by a dam sixty-four miles down the San Juan River, the outflow of the surplus waters of the lake. By means of this dam and embankments, the lake level is extended over a distance of 152 miles, of which there is free navigation in the lake, river, and basins of 143 miles, and in excavation, nine miles; the excavations at the sea level are designed to have a surface width of 320 feet and thirty in depth, making a fair rate of speed practicable for vessels, and to pass each other in transit. On the Atlantic side, where the sea-level canal to the first lock will be eleven miles, there is a diurnal tide of only twenty inches. Were it twenty feet, as at Panama, it would require a tide-lock to prevent scour and deposits. The country is entirely flat, and the heavy embankments of the material excavated, flumed to 200 yards or more from the line of canal, will make the surface drainage actually only that which falls on the area. This is a marked contrast with the great surface drainage that would damage every mile of the Panama Canal were it built. Long weirs on the basin of the San Francisco River, and on the right bank of the River San Carlos as proposed, will effectually protect the

rivers and basins from the effects of surface drainage. The two axioms of hydraulic engineers, abundant water supply and good surface drainage, are perhaps better met on this line of transit than on any canal of the same length on the globe.

The time supposed necessary to effect a lockage is very greatly exaggerated in the public mind. At the Paris Canal Congress, Sir John Hawkshaw put it at fifteen minutes. At St. Mary's Falls, where our Government has the largest lift lock known, with a lift of eighteen feet, a lockage can be effected in thirteen minutes. In the construction of the canal there is a deep rock cut nearly three miles long near Greytown; a good part of the material will be required to construct a considerable mole at the entrance at Greytown, and a dam at Ochoa; there is other heavy work in blasting and in deepening a part of the river and lake. Humboldt half feared that the cut between the lake and the Pacific might be considerable, when it is found only forty-three feet above full lake, and quite five miles of the navigable distance is made by means of an embankment. Looking at the deep rock cut on the eastern side, near Greytown, it is worth while to bear in mind that making it is purely voluntary, and far preferable, as a choice, to excavating less than twenty miles of additional prism, which would flank all deep cuts. I am not disposed to belittle the quantity of work that will be required to construct the canal, even in this locality, so favored by nature; especially in the fact that when a given part of the work is done, it will not be destroyed or even seriously increased by landslides and washes. Adding much to the economy, and quite unlike Panama, it has convenient dumping grounds along the whole line, and every part of the work can be attacked without interference as soon as the plant is in place, which will require time.

In the Paris Congress, I said that in the consideration of a ship canal across this continent, we may well suppose that its permanency should be regarded as important as the selection of the route itself, involving the least cost of construction with the minimum of problems of doubtful cost

in the execution of the work. With these points assured, the question becomes fairly debatable whether the physical conditions are to be considered too formidable to admit of the execution of the work as a commercial or monetary question—in fact, whether a grand idea for the amelioration of the great commerce of the world can be put in execution, or perforce abandoned, through the existence of obstacles too formidable in their nature to overcome them.

With the facts before him, as presented in the *Engineering News*, of September 14th, an engineer can form an approximate estimate of the cost of the canal. If money can be obtained without discount, it would cost one sum, if not, quite another sum. If the Government should take a first mortgage by guaranteeing three per cent. interest on $100,000,000 bonds for a term of years, the cost would be reduced to a minimum, so far as the money question is concerned. If the company has to look about and obtain funds at home and abroad, without other guarantee than the successful completion of the work, the cost of the execution of the canal would perhaps be widely different. In this case, the traffic of the world passing through the canal, and not the company, would eventually pay the difference in that much additional charge on toll rates. If owing to this and other considerations, the canal should cost $250,000,000, in my belief it would not be the less munificent in its reward to stockholders. With its moneyed support assured on a basis of three per cent. bonds at par as issued, the canal including interest on bonds, should not cost more than $150,000,000, if indeed that much. Should the company fail, the Government would be secured as a private and not as a Government owner. It could then complete the work with entire profit to itself, and control it as an owner, subject of course to all of the obligations and restrictions that the company entered into with the respective governments of Nicaragua and Costa Rica, and having no other rights or powers than belonged to the company through its concessions. As the collateral benefits that would be derived from the construction of the canal to the country would be many times greater than the benefits the

company would derive through its investment, it would seem an obligation on the part of the Government to enable the company to raise its money on the sale of stock and bonds without discount, the more as it would have ample security; a guarantee would only amount to a substantial expression as to the commercial practicability of the canal when completed, and as stated before, the toll rates being limited, after ten years, and dependent on the cost, would actually be that much of an economy, and just in proportion as it would free the company from a larger rate of interest and from the operations of "bulls and bears." I have already shown the intrigues of the Panama Canal Company, in Costa Rica, and M. de Lesseps, President of the Suez Canal Company, shows his hand now in Guatemala. These are questions that properly belong to statesmen and to financiers, with the fact demonstrable, that should the canal cost when completed $250,000,000, it would nevertheless be a sound, and soon after completion, a munificent investment. This of course must depend upon its traffic and the toll dues resulting. Look at a map, or better still, with a globe before you, cast a glance along the coast lines north and south from Brito, the intended Pacific port of the canal. Peopled as it is now, from north to south, this coast would in itself yield an enormous revenue. Look then toward Japan, the northern coast of China, the Philippine Islands, and in the southern hemisphere, the eastern coast of Australia and New Zealand. All of the traffic from these regions, not only with us but to Europe, would pass through the canal, save sailing vessels bound to Europe from Australia and New Zealand, that would pass around Cape Horn, and returning, through the canal.

There is one traffic alone, now of small dimensions, that will increase enormously as soon as the canal is available—the timber trade of the northwest coast to Europe and our eastern coast. We all know that the supply of the Atlantic water-shed is well-nigh exhausted, from use and destructive forest fires, and this includes Michigan and all that region. Governor Alger told a friend one year ago that it would not hold out longer than five years. In the Southern States

there is yet a considerable amount of yellow pine, but almost all of it is distant from lines of cheap transportation. On the Pacific slope, and even near the coast, there has been wanton destruction of timber, and recently forest fires have swept the country for hundreds of miles, so that the shores of Columbia River and of Puget Sound even, cannot longer be relied upon beyond furnishing local supplies and markets near at hand. Distant as the voyage was around Cape Horn, dozens of ships have made it yearly, laden with timber from Puget Sound to Europe and our eastern coast. Happily there remains an enormous region yet intact, extending northwest from Puget Sound, perhaps 600 miles, and having a mean breadth of 100 miles or more, an immense archipelago, with convenient channel ways, lying between long narrow islands, affording great facilities for transporting the logs to mills and loading lumber into ships when sawed. Nowhere on the globe are more economic means of cutting and loading than in Columbia River and Puget Sound, nor is there timber in quality found elsewhere in quantities as the yellow cedar and the firs of Princess Charlotte and the neighboring islands of the archipelago referred to. A canoe dug out of a yellow cedar log, eight feet in diameter and fifty-nine feet long, is to be seen in the National Museum in Washington. The mass of timber to the acre would astound even a Maine lumberman. The climate is damp and forest fires would be almost impossible; should they occur they would at most be limited to an island, and what adds greatly to the security of the timber, is the fact that the cupidity of man is appealed to in utilizing it to his profit rather than in destroying it to cultivate the land. This timber supply will last for centuries, but cannot be availed of except at great cost of transportation until the canal is made. On its completion hundreds of vessels will be engaged in carrying it to profitable markets, and the grain product, now quite considerable, and carried to Europe although handicapped by a Cape Horn voyage. These two products would form a very considerable part of the traffic for the canal were it now operative.

The *Engineering News* referred to, makes an admirable

comparison of the two canal routes, as follows: "At Nicaragua there is no unsolvable Chagres River problem; there is much less canal in excavation; there is much less deep cutting; there is no problem of water supply; there is no rotten sliding rock; there are no endemic pestilences; there is a stiff trade breeze blowing all the year round to maintain health and comfort; there is a prior knowledge from detail surveys of just what is to be done, which was wholly lacking at Panama; there is the advantage of all the experience gained at Panama; and of an official 'base' on this side of the ocean, instead of on the other side; and there is the practical certainty of far better management. These are enormous advantages, and it therefore seems to us that no reasonable man can doubt, first, that the canal can be built for $100,000,000 to $150,000,000 at the very most, and secondly, that it will be exceedingly profitable even at that rate."

That the Nicaragua Canal will be constructed, and without delay, is assured by these facts, which tell not the less why the Panama Canal was a failure and will never be completed. In the Paris Canal Congress, authorized by the Executive Department of our Government, I said that the people of the United States are not disposed to consider the construction of an Isthmian canal, solely with reference to the degree in which the commerce and interests of the United States will be relatively benefited through its construction as compared with the advantages that may accrue to other commercial nations. Such a ship canal cannot fail to be a great and common benefit, and especially in opening a rapid and easy transit between the Atlantic coasts of Europe and America with the western coast of America, and the speedy development of Australia. Regarding this inter-oceanic ship canal, when constructed, as the greatest artificial highway that can be constructed, conferring benefits on all nations and peoples, the people of the United States consider its construction as one of common interest, and the guarantee of its neutrality a duty in common to all nations.

MUNICIPAL ENGINEERING—A STUDY OF STREET PAVEMENTS.

By Lewis M. Haupt.

[*A lecture delivered before the* Franklin Institute, *November 8, 1889.*]

Professor Haupt was introduced by Prof. Coleman Sellers, and spoke as follows:

Ladies and Gentlemen:

Under peculiarly delicate and suggestive circumstances, the poet Burns produced the familiar epigram:

> "Oh! wad some power the giftie gie us,
> To see oursels as others see us!
> It wad frae monie a blunder free us,
> And foolish notion."

Although the circumstances and conditions are entirely different, nevertheless we may profitably invoke the same spirit to aid us in the investigations we are about to enter upon.

There are times in the life of every community, as in that of an individual, when such introspection becomes a necessity to the municipal, as well as the moral development. We must first become conscious of our defects before we can hope to correct them, and therefore a few words are necessary as to the existence and character of these defects.

In general, external appearances are the criteria of the internal directing forces, hence when one sees an individual clad in rags, the conclusion is reached that he must be either a pauper, a miser, a prodigal or a debtor, and that he is lacking in the energy and thrift which would lift him to a higher level.

Like causes will produce like effects, whether taken collectively or singly, and hence we will find that a community in which improper or inadequate provision is made for the

physical wants of its members, must be the victim of penury, debt, mismanagement or incompetency.

The visible evidence of such a condition, if it exists, are to be found in the public works of a great city, and the gauge can be most readily applied by comparisons.

But, since comparisons are sometimes odious, it should be understood from the first that these are presented, not for the purpose of reflecting upon the character of our public improvements, but that, as interested citizens and taxpayers, we may realize so fully and impressively our actual condition as to lead to prompt, definite and concerted action for their amelioration, should it be deemed to be necessary.

The question then before us may be thus formulated: Are we getting the best results obtainable for the money expended, or is there room for improvement in the character of our public works?

If we look to the press, as indicative of the public sentiment, for a reply, we will find a widespread and outspoken dissatisfaction. While we have not space to multiply instances, a few examples will suffice. At a recent dedication of one of our public schools, one of the speakers, an eminent judge of the Orphans' Court, in referring to false municipal economy, said:

> "There are two kinds of economy; one which cheapens the first cost of a commodity or an enterprise and reckons its losses afterwards, and another which counts nothing cheap at the outset which will not produce a profit in the end. In Philadelphia we have stuck with Puritan obstinacy to the economy of cheapness. We have cheap taxes and large debts. We have cheap pavements, which break up when we use them, and cheap sewers, which break up themselves. We have cheap court-houses, whose odors are more fatal to the jury than to the criminals, and cheap school-houses, which give steady employment to sextons and undertakers. There are times when we are without gas, but there is no season when we are without a gas bill; when we are short of water the city supplies us with mud, and charges us the same price for both fluids. It is about time to draw the line somewhere in this economy of cheapness."—*Public Ledger.*

Dr. Theodore L. Cuyler, in one of his letters from England, in the New York *Evangelist*, says:

We excel our British kinsfolk in the comforts of railway travel quite as

much as they excel us in the character of their country roads and city pavements. In fact, our city streets are mainly a relic of barbarism, in their roughness and indescribable filth. With the exception of Washington, there is hardly a city in America whose public thoroughfares are not for the most part a public disgrace. I dread the thought of exchanging this clean, smooth sea for the jolts and thumps of New York's and Brooklyn's unclean and unmerciful pavements. But for our fine elevated railways, locomotion would be a torment.

A recent number of an able, independent and influential periodical* contains these remarks:

Seeing that there is deep-rooted, although incomprehensible, prejudice in this city in favor of existing forms of sewers, in favor of the present sources of water supply and in favor of stone block pavements, it would be a good idea to have appointed a commission of scientific men, eminent in position and expert enough to command public confidence, to examine and report upon all these matters. There is, in fact, an absence of exact, full, authoritative information upon the involved subjects, every one of which touches closely the health, the comfort and the wealth of the whole body of citizens. We are about to appropriate large sums of money for water, sewers and pavements, and we affirm that most of the money is to be completely thrown away, because it is to be expended in an effort to improve a hopelessly botched job. We doubt if there is a quarter of a mile of sewer under Philadelphia that is constructed as a sewer ought to be; that is, as a water-tight conduit. We also doubt if there is a quart of wholesome water in the city outside of a drug store. We are positively certain that there is not a square yard of stone pavement that meets the requirements of modern civilization. It is worse than absurd for us to go scrambling along upon the old lines, throwing money away upon improvements that do not improve, etc.

This same paper, in another issue, emphatically says, in reference to the size of the city:

Mere bigness does not involve excellence, although men appear to regard it as the solitary thing of value. We have the greatest city hall on the continent, and on its high tower is to stand the largest statue in this part of the world; but what is there to boast of in that fact, if the people of Kensington have typhoid-tainted water pumped to them? We have the most extensive park belonging to any American city, but why should we contemplate it with satisfaction when every avenue leading to it is covered with a pavement that is disgraceful to a civilized community?

It adds, moreover, a deduction from these and other criticisms to the effect that—

Philadelphia will be truly great, be her dimensions little or big, when life

---

* *The Manufacturer.*

within her borders may be comfortable, cleanly, healthful and peaceful, and when her public affairs are controlled and administered by her wisest and best men, without any assistance from her criminal classes. * * * If she is to hold her place among American cities she will have to deserve to hold it by completely reforming the scandalous condition of her streets, her sewers, her water supply and the corruption that taints her politics.

Are these criticisms just? Does our city of homes merit the stigma that has been put upon her of being the worst-paved, worst-drained and worst-managed city of its size in the world?

These questions can be answered in part by comparing her public works with those of other cities of equal importance, yet there are persons who think it a sufficient answer to say that the death rate in Philadelphia is as low or lower than in most other places, and hence conclude that it is salubrious enough and there is no need of reform. But this is a mere evasion, for it is manifest to all that there are many removable causes of injury and disease existing, the absence of which might elevate this city to the enviable position of being the healthiest in the world. The present low death rate* may be attributed more to the absence of tenement houses than to general cleanliness of the streets and sewers or the purity of the water, yet the very extent of the city resulting from this spreading out of the population imposes another heavy burden upon the citizen in the shape of long distances to be traversed, for which no sufficiently rapid conveyances are available.

It is manifestly impossible for us to review so broad a field as that included in the public works of a city in the time devoted to this lecture, but as an instance of the character of these works, most of which, as well as their

---

* The death rate per thousand is for Rome, 28; for New York, 26·9; for Manchester, England, 26·4; for Vienna, 25; Boston, 23·23; Glasgow, 22·80; Brooklyn, 22·72; Paris, 22·50; Philadelphia, 20·72; Liverpool, 20·20, and for London, 18·70, but in consequence of the cleanliness of the streets and the improvements made in the tenement flats, the death rate of London has been lowered to 15·90 in 1888.

In 1887, the death rate in the improved tenements of London was only 12·5, or less than one-half of that in American cities.—*Phila. Ledger*, October 24th. Extract from a paper by Civil Engineer White, of Brooklyn.

cost, have come to us by inheritance, let us examine the *streets*, which are visible to every one having occasion to use them, whether denizen or alien.

Streets are fundamentally thoroughfares, designed to furnish means of communication from any part of a city to any other part, hence they should lead in every possible direction, and a plan which, as in the old city proper, provides for rectilinear movement in only four directions, is defective and imposes a restraint or a burden upon those citizens who are compelled to live on the diagonals. Again, the space taken for streets is deducted from the total area and is sustained by a general tax upon the remaining territory. It should, therefore, not be larger than is necessary for the purpose. This limit will be found to be at about thirty per cent. Moreover, the width of the various streets and avenues should bear some relation to the character of the traffic and dimensions of the vehicles intended to pass over them. It is no infrequent occurrence to find a blockade, caused by a coal cart or a moving van, backed against a curb. In many cases, also, there is a waste of space because there is not sufficient width between curb and tram-rail for any vehicle, either to stand or move. These defects become very apparent after the street is built upon and the traffic becomes large, and when it is too late to correct them, excepting at great expense. But there is another class of defects more manifest and more easily remedied, which relate to the

PAVEMENTS.

Although volumes have been written on this subject and mankind has been constructing pavements almost since the foundation of the world, the lessons of experience do not appear to have left a serious impression. We only know that our streets are intended to be paved with the best materials available, laid under carefully-worded specifications, and yet, in a few days or weeks, we find them developing weak spots, and yielding to pressure or rains, which make repairs necessary. Why is this and where is the defect? There can be but one answer and that is, because

a structure will not stand unless supported, and *a compressible soil is not a sufficient foundation for a street pavement.* Provide an unyielding substructure and the superstructure will last almost indefinitely. The fundamental requirements of a durable pavement are, a substantial foundation and a suitable wearing surface. *The vital defect of our city pavements is in the character of this foundation.*

Thus Section No. 7 of the Specifications for Block Pavements, whether of "granite," Pennsylvania, Lambertville or asphalt blocks, requires that "the foundation gravel shall be sharp, clean, free from top-soil, rubbish or perishable material, and contain by weight not more than fifteen per cent. of clay, loam, dust or material that will make mud, or be displaced by slowly-running water."

Hence, it appears that the foundation should be composed of carefully selected material, designed to furnish a porous cushion for the escape of surface or subsoil water. Since screened ashes possesses this property in an eminent degree, it has come to be regarded as a suitable substitute for the foundation gravel as required by the specifications. At least we must so conclude from the large quantity of ashes to be found underlying our pavements. The mere drainage of the subsoil is, however, but a minor function of the foundation. *Its main purpose is to carry the load and distribute it from the points of contact over as large a surface as possible. It needs no second thought to realize that an arch, or layer, of foundation gravel or of ashes, possessing little or no coherence, is about as poor a structure to perform this service as can well be devised,* and that the main reliance must be placed on the surface covering, both for strength and wear. If this covering is composed of small units, it possesses inherent elements of weakness at every joint, and the ability of the pavement to do its work will depend more upon the strength of the joints than upon anything else. Hence, the smaller the number of joints the better for strength.

But leaving the subject of the wearing surface for further consideration, let us look again at the foundation. We have just seen that it is inherently weak because of its material, let us now consider its dimensions.

Section 3, of the Specification, says:

Excavation and grading. "The street shall be excavated and graded from curb to curb accurately to sub-grade, fifteen inches below the finished grade; Laying of foundation course. then, covered with sharp foundation gravel, to be applied in sufficient quantity and thoroughly compacted by rolling or ramming until the new surface, from curb to curb, is The bedding course. exactly nine inches below finished grade; sharp washed paving sand or gravel shall then be spread upon the compacted foundation gravel to the requisite depth, Manner of setting the blocks. and the stone paving blocks at once put in place, being set vertically on edge, in close contact with each other, and in straight rows square across the street, except at Intersections. intersections, which shall be paved at an angle of 45° to the lines of the intersecting roadways. Precaution. Care shall be taken that blocks in the same row are of the same thickness and the same depth; that those in adjoining rows are so set as to break joints by a space of not less than two inches, and that when thoroughly rammed they will be brought to the exact grade, and give the desired form to the finished surface, making joints generally one-half inch in thickness, and at no point exceeding one inch in thickness."

From this it appears that the foundation course of gravel is to be six inches deep, when compacted, that it is then covered with sharp washed paving sand to the "requisite depth," and completed to grade by the blocks, laid in a certain manner, which is clearly defined, excepting as to the intersections. The clause, recently introduced, requiring the rows at intersections to make "an angle of 45° with the intersecting roadways" may refer to either of two directions at right angles to each other, one of which is good, being normal to the lines of travel around a corner; the other

bad, being parallel to the path of the wheels. Yet samples of both kinds are to be seen in some recent city work.

To determine what is to be understood by the "requisite depth," we must know the size of the blocks; which, for granite, are required to be:

"From 6 to 7 inches in depth, $3\frac{1}{2}$ to $4\frac{1}{2}$ inches in width, 8 to 12 inches in length, faces not warped, straight, free from bunches, depressions and inequalities exceeding one-half inch. The faces shall meet at right angles, and the corresponding dimensions of opposite faces shall not vary more than one-half inch, and no stones shall measure less than the above-named lowest figure."*

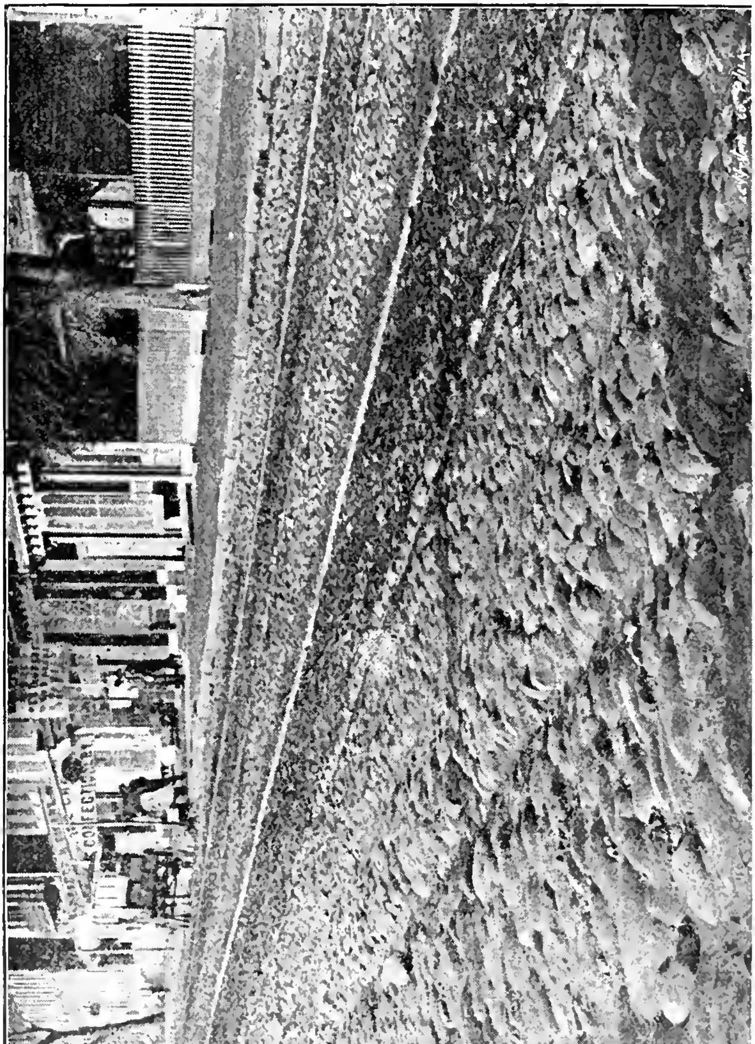
This will give for the bedding course from two to three inches, depending upon the depth of the paving blocks.

Viewing this structure then from an engineering standpoint, we have a bed of, at most, nine inches in depth, composed of material whose elements are incoherent and surmounted by a flat arch of voussoirs, or blocks, between which there may be joints of from one-half to one inch—while for abutments there are curbs, it may be eight inches wide on top, twenty-four inches deep and projecting five inches above the surface of the roadway. This structure is subjected, not to a uniformly distributed load, but to a succession of shocks, blows and vibrations from very variable forces, applied at any or every point of the surface, and at times when the foundation and subsoil may be saturated with water or upheaved by frost, for in most cases the pavements are not impervious, as they should be. The effects of frost in breaking up the continuity of such a surface are very great, but there is not time now to consider them. Already there is too much of detail, and yet I ask your indulgence for a few words as to the wearing surface. I shall not go into the subject of its conflicting and varied requirements, nor the material best adapted to meet them, as this ground has already been covered in my paper on "Street Pavements," published in this JOURNAL of May, 1877, but I desire to emphasize the fact that, as before said,

---

* Section 9, of Specification for Paving with Granite, etc.

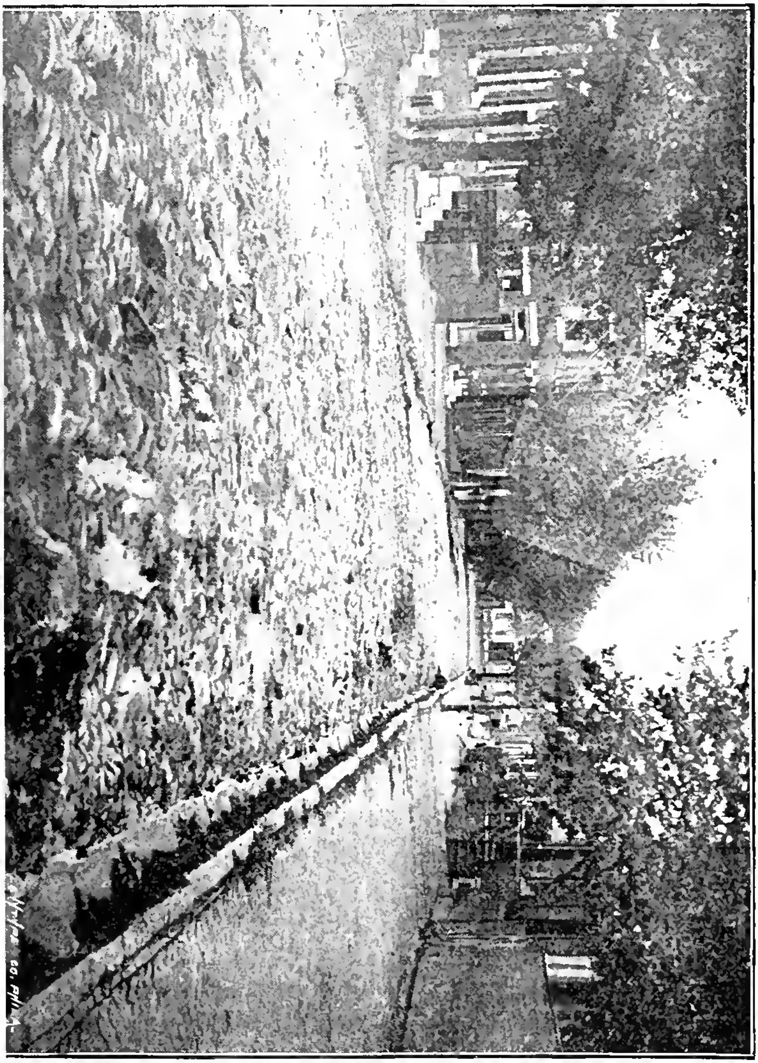
the joint is the weakest part of the surface, and, of all directions for the joints, that which is longitudinal or parallel to the line of traction, is the worst.



View of Rut-worn Street Pavement, 34th and Woodland Avenue, opposite University of Pennsylvania.

It follows, therefore, that the smaller the number of joints, and especially of longitudinal joints, the better, yet the pleas for their existence are based upon facility for handling

the material, foothold for the horse, and facility of removal. But pavements ought not to be laid with the expectation of having them broken into by every kind of service, as for



View of Street Pavement, Thirty-eighth and Warren Streets, West Philadelphia.

gas, water, electricity, sewage, heat or power. It is feasible to provide for these various conduits, without constant irruptions into the pavements. Elsewhere they are laid

under the sidewalks, or in subways provided for the purpose, where they are readily accessible for connections or repairs. Why not here?

Such a system of subways for traffic, as well as for all kinds of municipal service, should form the basis of a comprehensive plan for improving the physical condition of our city; then would permanent pavements become a possibility, and, as a consequence, the value of real estate would be greatly increased, and the revenues of the city be augmented correspondingly.*

But since we have not yet seen fit to require such an improved state of civilization, let us return to the consideration of our attempt to better our condition by the general introduction of the granite or other block pavement.

According to the specifications, these blocks should be laid in rows at right angles to the curbs, except at intersections, and the joints should overlap at least two inches. The blocks should not be less than eight inches in length nor more than twelve, and likewise the widths are restricted to between three and one-half and four and one-half inches.

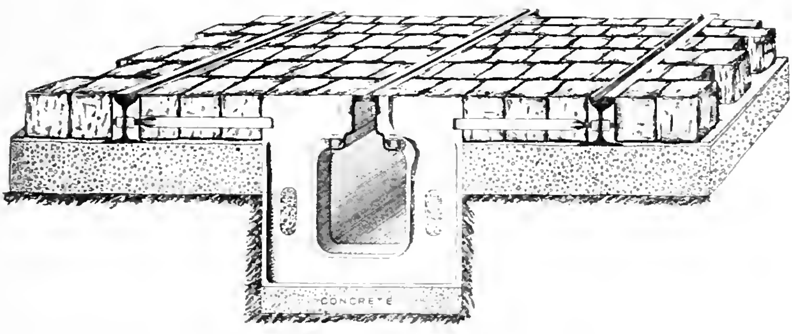
In comparing these and other limitations with the results as seen upon our streets, we must conclude that although specific and definite, they were intended to serve merely as guides to indicate the approximate positions and dimensions, as well as character of the materials used, for there has been great liberty taken in their interpretation. As a rule, such discretion has been exercised wisely and with improved results, especially in the matter of laying the longer axis of the stones at an angle of about 45° to the curb lines, within the squares, as has been done generally on Franklin Street, instead of at right angles; and of permitting the length of the blocks to exceed twelve inches, reaching, in some instances, to nineteen or twenty, thus reducing the number of longitudinal joints and increasing the inertia of the block. If the specifications are to be interpreted literally and strictly, our pavements would cost more, the contractors would be obliged to bring suits for their money

---

* Vide p. 8, Report of the Commissioners for District of Columbia for 1885.

and the roadway would not be as good in some particulars. I believe, however, that the specifications should be amended to permit greater latitude, and then be more rigidly enforced. But no specifications can provide good pavements on poor foundations, or when the surface may be torn up almost as soon as it is laid, to repair a defective sewer or make a house connection. These are inherent defects which may be and should be removed.

The foreigner visiting America, on being asked what impressed him most forcibly, replied, "the miserable pavements," while the American in his tour through the chief cities of Europe, is compelled to respond to the same inquiry, "the excellent condition of your streets." The visiting engineers and others who attended the Paris Exposition this



summer all concede the truth of the comparison, and are convinced that better pavements are not only possible but necessary, and far more economical. What constitutes the difference? It is to be found in both the foundation and the wearing surface. Abroad, the former is generally a monolithic arch of concrete, laid in hydraulic cement, from six inches to one foot or more in thickness; the latter, a surface either without joints, except where rails are laid, or with very close joints between stones, well bedded in concrete, and rendered impervious to water. These pavements are easily and cheaply cleaned, and cost very little for maintenance.

Again, looking at the surface covering from an economic standpoint, let us see how the power required to move a

given load is affected by the resistances of the various kinds of pavements.

The resistance to traction caused

By sand is $\frac{1}{5}$ or 20 per cent. of the weight of the load, or 400				pounds	per	ton.
" gravel it is $\frac{1}{10}$ or 10 per ct. of the weight of the load, or 200				"	"	"
" an ordinary earth road it is $\frac{1}{10}$th	"	"	or 200	"	"	"
" hard, dry clay or earth, $\frac{1}{20}$th to $\frac{1}{30}$th	"	"	or 100 to 66	"	"	"
" cobblestones, ordinary, $\frac{1}{8}$th	"	"	or 250	"	"	"
" good " small size, $\frac{1}{15}$th to $\frac{1}{30}$th	"	"	or 133 to 66	"	"	"
" ordinary macadam, $\frac{1}{25}$th to $\frac{1}{35}$th	"	"	or 80 to 57	"	"	"
" best French " $\frac{1}{50}$th	"	"	or 40	"	"	"
" ordinary stone block, $\frac{1}{25}$th,	"	"	or 80	"	"	"
" " Belgian " $\frac{1}{40}$th,	"	"	or 50	"	"	"
" well laid " " $\frac{1}{60}$th	"	"	or 33	"	"	"
" asphalt in sheet form, $\frac{1}{133}$d,	"	"	or 15	"	"	"
" smooth granite trams, $\frac{1}{166}$th,	"	"	or 12	"	"	"
" iron tramways, well laid, $\frac{1}{200}$th,	"	"	or 10	"	"	"

If, for purposes of comparison, it be assumed that it requires one horse to move a ton on an iron tramway, then we find that to perform the same work on the other surfaces there will be needed, for asphalt $1\frac{1}{2}$ horses; for well laid Belgian block, $3\frac{1}{3}$; for ordinary Belgian, 5; for ordinary stone block, 8; for macadam from 5·7 to 8; for good cobbles from 6·6 to 13·3; for ordinary cobbles, 25; for a good earth or gravel road, dry, 20; and for sand, 40 horses. That is, to move the same load at the same speed and for the same length of time, with the same fatigue to each horse, requires, for *ordinary cobble stones 25*, and for *stone block pavements 8 times the number of horses necessary for iron trams*, while for asphalt only $1\frac{1}{2}$ are required. The great economy of smoothness, therefore, becomes at once apparent, but it is evident that, as in all lines of transportation, the greatest resistance regulates the load over the rest of the route, unless there be auxiliary power, so the continuity of the surface should remain unbroken by any other grade of material which would increase the resistance. It is estimated that if New York were paved throughout with asphalt, "the traffic that now costs $15,000,000, would be done for a fraction of that sum," and that at least $1,000,000 more could be saved in repairs on vehicles and for horses annually.*

* *The Manufacturer*, March 1, 1883.

Instead of reducing the number of horses, however, as a matter of fact and in accordance with the general maxim that *facilities beget traffic*, their number would be greatly increased, because of the real pleasure derived from riding over comfortable pavements. This ability to move readily over any part of the surface instead of following in well defined grooves as now, would also have the effect of greatly reducing the rates of fare by the establishment of other lines. Thus, in London and Paris the fares are much lower than in American cities for municipal traffic, while for general traffic, outside of the cities, our railroad rates are far less than those abroad.

A few remarkable facts concerning the increase of traffic and reduction of rates in London will bear repetition. Just prior to the opening of the underground railway, the London General Omnibus Company carried about 40,000,000 passengers annually, and the fare was seven cents. In consequence of the competition of rail and tramways the average fare is now about four cents (two pence) and the number of passengers has increased to 75,000,000 for each of the companies. The average cost to the omnibus company is three and one-half cents, and it pays twelve and one-half per cent. dividends from its surplus.

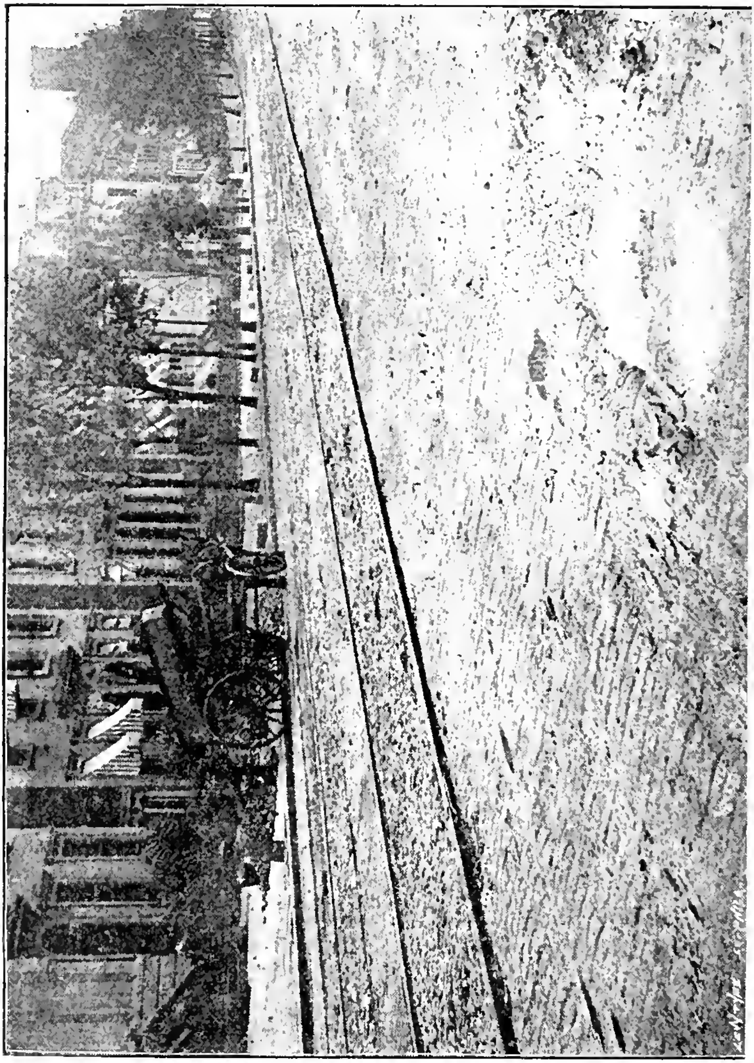
On the tramways the average fare is about three cents, and the cost about two and one-half cents per passenger.

The normal increase in traffic has been at the rate of ten per cent., and the total increment in twenty years was 470 per cent., while in the same period the population only increased thirty-six per cent.

On the London stages the fares are modified according to the distance, and will average in some localities only one cent per mile. The seating capacity of the omnibus is twenty-eight, or twelve inside and sixteen on top. They are drawn by two horses. In Paris some of the stages have three horses abreast, but there the rolling stock is larger and heavier.

The Paris General Omnibus Company make and repair their own vehicles, and in this service over 600 men of different trades are employed. Their wages in 1888 amounted to upwards of $268,000.

There are 1,600 vehicles of different models. Of these 1,000 are for passenger service in Paris, and they make a daily run of 55,800 miles, or about fifty-six miles each. They

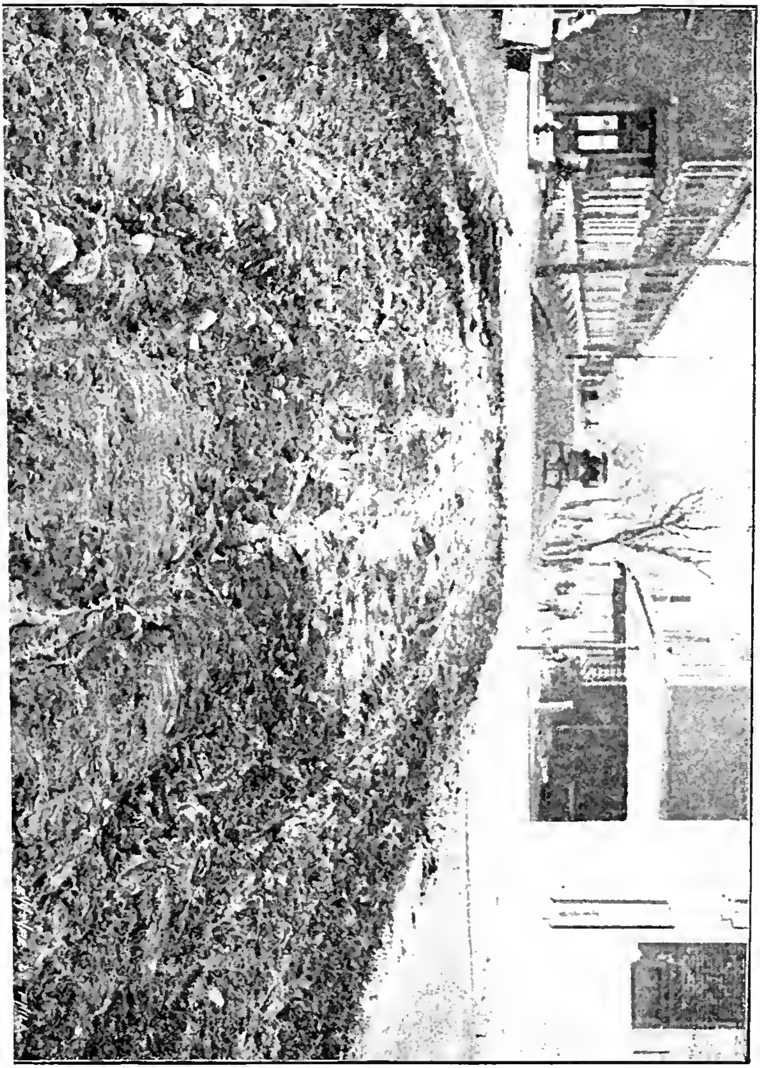


Asphalt Block Pavement, Spring Garden Street, West of Eighteenth Street.

all have an imperial or upper deck, to which ladies are admitted when riding on the tram-cars, three-horse coaches or the new two-horse patterns.

The number of passengers carried in 1888 was 181,215,288.

A two-horse omnibus of class 1 will carry thirty persons, and to prevent overcrowding as well as to insure a seat,



View on Mifflin Street, below Front, looking West.

numbered checks are given to passengers at stations on the route. These are collected by the conductor on entrance, and when all the seats are filled, a placard marked "Com-

plet" is exposed and kept up until some one alights. A three-horse omnibus will carry about forty-four passengers seated, while our street cars have a capacity of twenty seats. This, compared with the two-horse omnibus, would show an economy in favor of the latter of fifty per cent.

We have thus briefly reviewed the fundamental defects of pavements, and the benefits accruing from their improved condition. Let us now look for a moment at the relative cost.

In their report to his Honor, the Mayor of this city, in 1884, the Board of Experts appointed to examine into the condition of our street pavements, say:

"The cost per square yard of the standard pavements which we recommend, is as follows:

Seven-inch granite blocks on concrete foundation, ...	\$3 65
Six-inch " " " gravel "	2 60
Sheet asphalt on concrete foundation, ...	2 25
Asphalt block on " "	2 90
Asphalt block on gravel "	2 10 "

They further estimate that at that date there were 535 miles of streets paved with cobblestones, containing in round numbers 9,000,000 square yards. Of this distance 203 miles is traversed by street railroads. Then follows their estimate for repaving, which aggregates \$21,095,000, to be spent at the rate of say \$2,000,000 per annum. In making up this estimate it was suggested that 1,000,000 yards be of granite on concrete at \$3.65; 1,100,000 of sheet asphalt on concrete at \$2.25; 300,000 of asphalt block on gravel at \$2.10; and the balance or 6,000,000 yards of granite on gravel at \$2.60. This is over seventy per cent. of the entire amount proposed to be covered by a surface which, as has been shown, offers more than five times the resistance to traffic than asphalt; is very permeable, has a weaker foundation and costs thirty-five cents more per square yard.

The wisdom of this recommendation does not therefore appear, unless it be on the score of durability; but when the cost of maintenance of these two kinds of pavement is compared, there is so little difference as to leave virtually no choice, for whilst the improved asphalt surface will wear

down more rapidly than granite, the latter will require more labor in consequence of its defective foundations.

Since this report was submitted the use of vitrified brick has become quite popular, and for light traffic has given some very satisfactory results.

In this city it has been extensively introduced in West Philadelphia and other districts, where it is laid upon a nine-inch bed of fine gravel covered by two inches of "clean bar sand."

A brick pavement of this description has been in use in Charleston, W. Va., for sixteen years, and is said to have cost nothing for repairs or maintenance. As the joints are laid close and filled with cement, it makes an impervious covering at a low cost and provides a good wearing surface when the bricks are of good quality.

The cost of new pavements in the outlying districts could be materially reduced, by keeping the grades of the streets or roads a few inches below the approved city or district grades, so that the original road surface, whether it be of macadam, gravel or even cobblestones, might be used for the foundation of the subsequent wearing surface,* thus avoiding the removal of the original surface and the preparation of a new foundation.

The best disposition to be made of existing cobble and rubble pavements, would be to crush the stones up for the concrete to be used in repaving.

THE FINANCIAL QUESTION.

After all, when we have determined what is the best and most economical kind of a pavement for given conditions, we are confronted with the more important question of providing the means to carry on the work.

Here the way is hedged in by laws and ordinances, limiting the power to raise money and prescribing the manner of paying for the work when done, to such a degree as to constitute a serious obstruction to any public work of this kind when undertaken on a scale of so great magnitude.

* This idea was first suggested by the writer, in designing a revised plan for the streets of Superior, Wis., in 1882.

To *borrow* the money, as has been suggested, is merely to put off the evil day upon our children, who will inherit the worn-out pavements with their cost. As well might we borrow money for our raiment and bequeath to posterity the bills with the tattered garments.

Again, to pay for work done by assessment bills on the adjacent properties, embracing rich and poor alike, is in many cases a great hardship and is almost equivalent to giving to the contractor authority, in the name of the city, to turn the artisan, who may be buying by instalment, out of doors.

To raise money by increasing the tax rate is undoubtedly the best plan, but even this appears unjust, as throwing the burden, of the improvement mainly upon holders of real estate, who pay their pro-rata in the taxes and are then levied upon for assessments in addition.

Is there no way, under the Constitution, whereby a special improvement tax could be collected from all classes of citizens? This is a question for Councils, and not for us to consider. If feasible, it would distribute and lighten the burden, the funds would be provided regularly, as required, and the streets of this city would be made to fulfil their purposes of providing means of communication with a minimum of resistance and cost. It is the honest policy of "pay as you go" and is the cheapest in the end, provided in every case that the work be properly designed and faithfully executed.

The city of Washington is far in advance of any others in regard to its pavements, since it is not restricted in its finances and its municipal works are under the direct supervision of an engineer commission, which has given much attention to the problem of pavements. It has already about eighty-one miles of streets covered with asphalt, and it has also introduced extensively the grooved girder rail so universally used on the continent.

STREET-CAR TRACKS.

The tram-ways, or street-car tracks, as laid in our cities, are a continual source of trouble and give unsatisfactory

results. But nothing else can be expected from a structure whose foundation is an unpreserved, and frequently an unseasoned, vegetable substance. To lay a side or centre-bearing, flat, iron rail upon a wooden stringer, having a continuous vertical joint on either side to admit water, and forming a rut for wheels, is unscientific and destructive to both the rolling stock and the way. Moreover, it induces traffic to follow the lines of the trams instead of permitting it to take any part of the pavement with equal facility. As a rule the rails are warped in both directions and the counter-sunk heads of the spikes are worn off, leaving in many places a sprung rail and depressed joint, which produces the destructive oscillations so noticeable on many lines.

The form of rail used in New York is even worse than here. It is so bad that the last mayor felt obliged to recommend its removal in the strongest language.

The rail which is found to fulfil the requirements of street travel best abroad is a grooved girder-rail, six inches deep, with a bottom flange four and one-half inches wide. The head is about four inches wide, of which two inches are for the tread and one inch for the groove.* This slight channel is ample to guide the cars and has no effect upon other vehicles, either in crossing or following it.

To form practically a continuous rail, the ends of each are bevelled at an angle of 45° so as to overlap, and as they are firmly bedded on a concrete base and filled up with concrete or asphalt, they are very durable and remarkably smooth, forming a delightful bearing surface, in strong contrast to our own cheap and unmechanical makeshifts.

Boston and Washington have already introduced this form of rail, and the Highway Commissioner of New York is on record as saying: "I have made up my mind to refuse permits in every case unless the railroad companies will agree to lay such rails as I require. The rail that I shall insist upon is a grooved rail, with an opening $\frac{15}{16}$ of an inch

* Samples of this rail were kindly furnished by the Johnson Street Girder Rail Company of Johnstown Pa., where it is now manufactured.

wide. No wagon wheel can be caught in this rail, and it can be crossed at any angle with safety. I propose to adhere to the position I have taken until I am overruled by the Courts."

A similar resolution on the part of our local authorities would give a result which would be beneficial to the street-car companies, to the public and to the city.

THE FOOTWAYS.

The sidewalk nuisance is another point upon which much might be said, but a long-suffering community seem to regard the use of the sidewalk for storing and displaying goods or empty boxes as either a privilege or a necessity, and prefer to take to the roadway rather than wait until a dray-load of cotton, sugar, china or other merchandise can be discharged by skids into the front doors of the stores or warehouses. While the majority of our streets are sixty feet wide, giving thirty-four for roadway and thirteen on either side for pedestrians, nearly half, and in many places more than half, of this is obstructed by projecting steps, signs, showcases, gratings, trees, fire-plugs, telegraph poles, cellar-doors, lamps and letter-boxes, carriage-blocks, hitching-posts, news and fruit stands and an occasional pump, to say nothing of the contents of the stores which are exposed for sale daily on the pavements.

It may, therefore, appear to be a restriction of personal freedom to learn that in London trucks and wagons are not allowed to back up against the curb and to place a plank across the pavement; packing cases and barrels are prohibited under the strictest police regulations from being placed on the sidewalk. Neither is it permitted to dump coal, unload barrels or any articles whatever upon the streets between 9 A.M. and 6 P.M., but all merchandise is required to be handled directly by cranes attached to the buildings or warehouses and reaching to the drays in the streets, or in bags or baskets. Thus the latter are preserved for the legitimate purpose of transit.

In selecting my subject, it was with the intention of making a general comparison of some of the various munic-

ipal improvements at home and abroad, such as the sewers, docks, city trams and conduits, but the great and urgent need of our pavements and the belief that we are not proceeding in such a way as to obtain the best results for the money expended, has induced me to confine my attention mainly to this latter subject. When it is remembered that to replace the existing cobble and rubble pavement will cost from $20,000,000 to $25,000,000, it becomes a serious matter, and it is important that we should start right. If this money were raised by loans, the interest on it would be $1,000,000, at four per cent., and were it not for our present unfortunate inheritance of debt, thirty-five per cent. of our income from taxes, or nearly *four and a half million of dollars* annually might be applied to public improvements, without increasing the rate one cent.* Yet it is seriously proposed to perpetuate this evil in an aggravated form.

In conclusion, let us now gather up the threads of this mottled fabric and fix in outline the pattern it has revealed.

We have seen that our pavements, as laid, are radically defective, being structurally weak and ill adapted to their purposes; that the foundation is inefficient and the surface covering in most cases such as to oppose far more resistance to traffic than is necessary; that it involves a waste of power and an excessive wear; that the constant breaking into the streets for repairs to sewers, for laying mains and for house connections is a serious evil that should be avoided.

That the form of tracks used for tram-rails and their foundation are alike inferior to modern requirements and far behind the present state of the art of street railway building.

That the specifications are so worded that a strict interpretation of them would either prevent any one from bidding or greatly increase the price of the work.

That the method of paying for these improvements by assessment bills is obnoxious and an obstacle to the passage of ordinances for the proper paving and grading of many of our streets.

---

* The assessed value of taxables for 1889 is $688,713,518, at $1.85 per $100, gives for the revenue from this source $12,646,199.75.

That a system of subways should be constructed by the city for the various kinds of municipal service, and be rented to the private corporations desiring such privileges. The revenues from these rentals as well as the reduced cost of cleaning and maintaining the pavements would abundantly compensate the city for the cost of the work.

That the use of the sidewalks for storing, exhibiting and packing goods constitutes a serious nuisance. That the grades of new streets and avenues should be kept below the final surface to serve as a base for the subsequent pavement, thus saving large sums for excavation and reforming of foundations.

That the wearing surface should be as free from joints as possible, especially if they are longitudinal, and that the smoother the surface the larger the traffic will become.

The mere recital of these defects is sufficient to suggest their appropriate and manifest remedies, which it rests with us, as citizens, to apply.

They embrace three distinct lines of action: (1) the preparation of a systematic plan for streets and conduits under engineering supervision; (2) the formulation of a more equitable plan for raising the means wherewith to pay for extended improvements, and (3) provision for the rapid and thorough execution of the works.

Having now reviewed briefly what may be called the theoretical side of the subject, let us look at some of the practical results obtained at home, as well as abroad, correcting our impressions and judgment by means of the comparisons.

This series of fifty-four slides has been carefully prepared to show the various types of pavements and their ordinary defects, from the best to the worst, including sheet asphalt, brick, stone block, asphalt block, cobble and rubble, with curbs, trams and the various features of street obstructions, broken sewers and machinery for sweeping.*

NOTE.—About thirty of the views were selected from the

* The JOURNAL is indebted for the use of the foregoing specimen illustrations of street pavements in Philadelphia to the Philadelphia *Sunday Mercury*, which published an abstract of Prof. Haupt's lecture.—COM. PUB.

streets of Philadelphia which were contrasted with those of London, Paris, Amsterdam, Newcastle, Vienna, Stratford-on-Avon, Rome and Pompeii.

PHILOSOPHY OF THE MULTI-CYLINDER, OR COMPOUND, ENGINE; ITS THEORY AND ITS LIMITATIONS.*

By Robert H. Thurston, Ithaca, N. Y.

Were it possible to construct a steam-engine of which the theory should be purely thermodynamic, an engine in which the only waste of energy should be that known as the necessary thermodynamic loss, its theory would be most simple and most satisfactory. The efficiency of the engine and the quantities of heat, steam, and fuel demanded for its operation at a given power, would be simple functions of the physical properties of the steam and of its ratio of expansion. The engineer, in constructing its theory, would only concern himself with the quantity of heat imported into the machine, the temperatures of the initial and terminal portions of the expansion line, and the relation of initial to back pressures. As was well stated by Rankine, a generation ago, nearly, the essential facts are the magnitudes of the pressures and volumes of the steam and the extent of adiabatic expansion, and it matters not whether the engine be one of a single cylinder or a multi-cylinder engine of indefinitely extended complexity. For this, the ideal case, as the writer has been accustomed to call it, the indicator diagram represents precisely the amount of transformation of heat-energy into mechanical work, and the ratio of its measure in units of work to the mechanical equivalent of the total quantity of heat-energy supplied to the engine, while doing that work, is the measure of the

* Presented at the Twentieth Meeting of the American Society of Mechanical Engineers, held in New York, November, 1889. Revised by the author for publication in the JOURNAL, and printed by permission from advance sheets of the Society's *Transactions*.

efficiency of the engine; as it is of the thermodynamic efficiency of the working fluid. The thermodynamic efficiency, the dynamic efficiency of the machine, and the total efficiency of the engine are here identical.

To ascertain how much heat, steam, and fuel are demanded by such an engine for the performance of work, it is only necessary to measure the quantity of work done by the steam upon the piston, as shown by the indicator, and to divide this quantity by the energy received by the engine from the boiler; the quotient is the efficiency of the engine. As the operation of the engine approaches more nearly the conditions of best effect, the magnitude of this measure of efficiency approaches a limit which is expressed by the quotient of the range of temperature worked through to the absolute temperature of the working fluid at entrance into the engine. Were all heat received completely utilized and the full thermodynamic equivalent realized in work performed, the quantity of steam demanded per hour and per horse-power, under the conditions now common in practice, as to initial and final temperatures, the engine being assumed perfect, structurally, would be about two and a half pounds, for efficiency unity, or not far from ten pounds for the best real cases, no wastes occurring. The excess of the actual consumption of fuel, in the best engines, above this last figure measures the sum of all wastes in real engines due to imperfections other than of thermodynamic cycle. Thus, the best work of the Corliss mill-engine may be taken as about sixteen pounds of steam per horse-power and per hour, where the thermodynamic efficiency is as just assumed, about twenty-five per cent. The wastes amount, in this case, therefore, to about six pounds per horse-power and per hour, or sixty per cent. of the ideal consumption. This comparison is easily made by a method first presented in full by Rankine, a generation ago, and which enables the thermodynamic efficiency to be easily computed for any given case.* Examples will be presently given of its application.

---

* *The Steam-Engine and other Prime Movers*, pp. 383–412.

The wastes of the steam-engine comprehend two principal classes: the external and the internal wastes; and these latter are of two distinct kinds. We may classify them thus:

(1) External wastes; consisting of those losses of heat without transformation which are produced by the conductivity and the radiating power of the materials of which the heated parts of the engine are composed. Heat which might otherwise be utilized by conversion into mechanical energy, is conducted or radiated to the adjacent parts of the engine and to surrounding objects.

This form of waste is of small amount, comparatively, and can readily be kept down to an unimportant proportion of the heat supplied from the boiler by properly covering exposed parts of the engine with non-conducting covering. Five per cent. should probably represent as large a percentage as is to be reasonably expected in good practice.

(2) Internal wastes; consisting of two parts:

(*a*) Thermodynamic, unavoidable, losses of heat rejected at the lower limit of temperature of working fluid;

(*b*) Wastes by internal conduction and storage of heat, followed by later rejection with the exhaust steam.

To these are to be added:

(3) Wastes of mechanical energy.

Of these losses, the first, (*a*), represented by the fraction, as a minimum, $\frac{T_2}{T_1}$ of the heat supplied, is, for any given set of initial and final temperatures of working fluid, a fixed and irreducible quantity, and one which measures the defect of efficiency of the perfect engine working between the given temperatures. The second, (*b*), is a quantity of variable amount, capable of amelioration by one or all of several known expedients, and reducible from the enormous proportion observed in small and ill-designed or badly constructed engines to a very moderate amount in large engines of good type. The last item, (3), is one which is seldom large in good constructions, as compared with the magnitudes, at least, of the other kinds, and may in some cases, by careful design, good construction and skilful manage-

ment, be brought down to less than five per cent. in non-condensing and to perhaps ten per cent. of the total energy in condensing engines of simple forms and high mean working pressures. The unavoidable thermodynamic waste is rarely less than seventy-five or eighty per cent., and the internal wastes by conduction and storage with subsequent rejection, by cylinder or internal condensation, as it is customarily called, and by leakage, range from ten per cent., as a minimum, perhaps, to twenty-five or thirty per cent., in good engines, to fifty per cent., in many cases, and even to much more than the latter proportion in exceptional cases. It is this which constitutes, ordinarily, the great source of loss and inefficiency of the real, as distinguished from the ideal engine. Leakage, in well-built engines, may be neglected as unimportant; but internal condensation is usually both serious in amount and extremely difficult to check effectively.

Since it is easy to prevent serious losses by external transfers of heat, by leakage, or by friction of engine, and since, as is well understood, the thermodynamic waste is unavoidable, and for any given case unalterable by the engineer, it is obvious that the direction in which he must look in his endeavor to further improve the economical performance of the engine, is that which leads towards the reduction of internal wastes by cylinder condensation.

The method of internal waste by condensation, as is now well and generally known, and as is now shown by all authorities,* consists in the absorption and storage of heat in the metal constituting the internal surfaces of the cylinder, at the commencement of the stroke, and to an extent which is determined by the difference of temperature at the moment existing between the prime steam and those surfaces which have been exposed, during the exhaust stroke, to the cooling influence of the comparatively cold steam passing into the condenser or into the atmosphere. This stored heat is, later, rejected during the terminal portion of

* See especially the works of Clarke, Hirn, Isherwood, and Cotterill, and more recently of Dwelshauvers-Dery.

the expansion period, and during the succeeding exhaust stroke, to the mass of steam exhausted, in its turn, at the opening of the exhaust passages. The quantity so wasted varies with the weight of steam worked thermodynamically each stroke, with the area of surface exposed to this action, with the period of exposure, and with the range of temperature worked through during the cycle. It is thus always an increasing quantity when the ratio of expansion is increased, and as the size of engine doing a given amount of work is increased; it is diminished by increasing engine-speeds and by any expedient which reduces the storing capacity of the interior of the cylinder. Since it is always an increasing function of the ratio of expansion, there always will be found, in any engine and under any given conditions of operation in other respects, a point beyond which further increase in the magnitude of that ratio will result in a loss by cylinder condensation greater in amount than the gain due to extended expansion, a circumstance which has been now known, for many years, as placing an early limit to the expansion of steam, and to the gain to be anticipated as a consequence.*

The method of variation of this waste was qualitatively determined by Clarke about 1850, was roughly gauged by him, both as to magnitude and as to its effect in limiting the ratio of expansion; was quantitatively investigated by Hirn and by Isherwood afterward, and was finally made the subject of an investigation, under the supervision of the writer, by Messrs. Gately and Kletsch, on a plan sketched out by the writer some years earlier,† in which it was endeavored to ascertain with some degree of accuracy the method of variation of the waste with variation of each of the essential conditions affecting and determining it. The result of this research in brief was to show that the waste varied, in the cases studied, sensibly as the square root of

---

* *Trans. Am. Soc. Mech. Engrs.*, 1882, *et seq.*; *Trans. N. Y. Acad. Sci.*, 1882; *Brit. Assoc. for Adv. Sci.*, 1884; this JOURNAL 1882, *et seq.*

† This JOURNAL, Oct. and Nov., 1885. *Trans. Am. Assoc. for Adv. Sci.*, Ann Arbor Meeting, 1885.

the ratio of expansion, and as the time of exposure, and was subject to a very slow decrease as the pressures adopted increased, the engine being worked condensing; decreasing about twice as rapidly, the condenser being thrown off.*

Variation with ratio of expansion was also capable of being expressed with great accuracy by an hyperbolic expression, the product of areas of surface exposed up to the point of cut-off and the percentage of condensation being found sensibly constant. Under ordinary working conditions, the steam pressure being about sixty pounds per square inch, by gauge, the cut-off at one-third, and the speed of piston 554 feet per minute, and of rotation sixty-eight revolutions, the condensation was about one-third, or the equivalent of fifty per cent. of the total consumption of a similar engine having a non-conducting cylinder, and thus free from this waste. Reduced to quantity of steam and of heat wasted, per square foot of surface exposed to point of cut-off, per minute of exposure, and per degree of range of temperature between prime and exhaust steam, Professor Marks finds the co-efficient to be 0·02 pounds, or 18 B.T.U., nearly, a result closely confirmed by the investigations of the same author, taking Hill's experiments for comparison, and also corroborated by the later work of other investigators.

These facts and laws being established, it becomes possible to determine the behavior of steam entering any given cylinder, and its method of working and of waste in any engine. Common experience, as well as theoretical considerations based upon the investigations already made, prove that it is impossible to expand steam in the ordinary single-cylinder engine with satisfactory gain of efficiency, beyond a point variable with the conditions assumed, but which may be roughly taken as not far from that giving a ratio of expansion equal to about one-half the square root of the steam pressure, measured from vacuum for the condensing engine of common type, or as measured by gauge for the

* The proportion thus wasted in these experiments were from $0·18 \sqrt{r}$ to $0·19 \sqrt{r}$. The writer takes $c = 0·2 \sqrt{r}$ in later work.

non-condensing engine. The waste by internal condensation increasing as the point of cut-off is shortened up, the loss, after a time, compensates the gain by increased expansion, and a point of maximum economy is passed at a very early stage for the older types of engine and later, but still at a comparatively low value of the ratio of expansion, for modern engines. For example, the old beam engine, such as was used in American rivers, or in the coast trade, a generation ago (1850), with steam at twenty-five pounds by gauge and a low piston speed, had a ratio of initial to back pressure plus friction of about 8 to 1; but its best ratio of expansion for efficiency of fluid was about 2 or 2½. The same type of engine, later, with twice the pressure per gauge, had values of these two ratios of about 16 and of 4 or 5 respectively. The ratio of expansion for maximum efficiency of working fluid was thus but about one-fourth that which thermodynamic theory, unqualified, would dictate. As engines have been improved this discrepancy has been reduced, but it still remains, with the best of engines, considerable.

The amelioration of wastes thus becomes an important matter. It thus happens that the efficiency and economy of operation of the single cylinder, the "simple" engine, is at all times limited by this very serious internal waste, and the question which all engineers since Watt have been endeavoring to solve, is: In what manner may we best proceed to eliminate or ameliorate this loss. The three methods which have been found advantageous, and, in special cases, fairly effective, are:

(1) Superheating.

(2) Steam jacketing.

(3) "Compounding."

It is evident that, if the steam can be introduced into the engine at such a temperature that the cooling action of the metal of the cylinder will not cause its condensation initially, and the stroke may be performed without condensation in consequence of doing work, no loss of heat from the cylinder can take place by re-evaporation; and if no such loss occurs, the waste of heat at entrance, in turn, by initial

cooling, will be reduced. Superheated steam, also, is a non-conductor and a non-absorbent of heat, precisely like the permanent gases. It is thus, also, less liable to this waste. But it is found in practice that superheating beyond a very moderate degree, perhaps 100° F., is inadvisable on account of risks of injury to engines and cost of repairs to super-heater, which more than compensate its advantages. It has come to be regarded as an auxiliary in economizing, not as a remedy for interior wastes.

Steam-jacketing is another and a common partial remedy for this waste. By surrounding the steam-cylinder with the steam-jacket, it is possible to produce, in part, the effect of superheating; that is to secure dryer steam in the engine throughout the stroke. The amount of re-evaporation, during the period succeeding cut-off and up to the closure of the exhaust-valve, and the quantity of heat of which the cylinder is thus robbed, measures the amount of initial condensation and waste and the weight of steam which must be supplied in excess of the thermodynamic demand to compensate that loss. The effect of the addition of a steam-jacket depends upon the conditions of operation of the engines, largely, and may be productive of marked advantage, or under unfavorable conditions, of no important useful effect. With steam initially dry or superheated, the jacket is probably always decidedly helpful; but, with wet steam, it is of comparatively little value, even if not sometimes a positively wasteful adjunct. High-speed engines derive less advantage from its application than slow-moving machines; and compound, or multi-cylinder engines are less dependent upon it for economy than are simple engines. The saving effected in ordinary cases, by its use, may be taken as averaging about twenty per cent.; and about the same gain is attained by effective superheating within the usually practicable range. The two devices in conjunction may be expected, ordinarily in mill engines, perhaps, to give a gain of something like thirty per cent. as compared with the standard forms of unjacketed simple engine working with slightly wet steam. The addition of either expedient to the latter practice, if properly performed, con-

siderably increases the magnitude of the ratio of expansion at maximum efficiency of fluid. Where it would ordinarily be approximately equal to one-half the square root of the pressure, as above, it might become, with superheating or with steam-jacketing, a figure as much as thirty or forty per cent. higher; and both expedients together might nearly double the profitable ratio of expansion. The assumption is commonly made that the superheating is retained throughout the stroke and that steam-jacketing may be relied upon to keep the working charge dry and saturated throughout the stroke; but neither of these hypotheses, as employed in the theory of the engine, is practically correct.

"*Compounding*," or the use of the multi-cylinder engine, in which the steam exhausted from one cylinder is again worked in a succeeding one, is the most familiar of devices for extending the economical range of expansion and increasing the efficiency of the engine. The limit to the useful extension of the expansion of steam in a single cylinder is found to be determined by the magnitude of the wastes incurred in the operation of an engine of which the working cylinder is a good conducting material. Any method of reducing this waste of heat internally will enable the efficiency of the engine to be increased by further profitable extension of the ratio of expansion. Common experience with the best constructions, and considerations which need not be here reviewed, show that the engineer may reasonably expect, by good design, construction and management, to secure an economy of steam which is fairly measured by the following table, the ratios of expansion, r, taken being, for each case, those which give best results for a given engine: *

STEAM PER HORSE-POWER PER HOUR, AT BEST RATIOS OF EXPANSION IN BEST ENGINES.

r	3	4	5	6	7	8	10	12	15	20	25	50	75
lbs.	32	27	25	22	20	20	19	17	16	15	15	1·1	0·9
kgs.	15	12	11	11	9	9	9	8	7	7	7	0·5	0·4

and ten per cent. better figures than these have been actually reported in peculiarly favorable cases.

* "Several efficiencies of the Steam-Engine." *Trans. A. S. M. E.*, and this JOURNAL, 1882.

Assuming it to be possible to divide the waste by cylinder condensation and leakage by two or more, it is evident that the limit to economical expansion and transformation of heat into work will be set correspondingly further away. This is precisely what is done by the multi-cylinder engine. The internal wastes are reduced approximately to those of one of its cylinders, and the gross percentage of waste is made less in the proportion of this division. The heat and steam rejected as waste by internal transfer without transformation from the first cylinder, is utilized in the second nearly as effectively as if it were received directly from a boiler at the pressure of rejection from the first cylinder. In so much, therefore, as the pressure can be increased and the increase utilized by the addition of another cylinder, gain is secured. If the total ratio of expansion can thus be raised, under the best working conditions for each case, we will say, from four up to eight, we should hope to secure a reduction of coal consumed from two and a half, we will say, to two pounds per horse-power and per hour, which is about the average figure in good practice.

The practical questions thus meet the engineer: To what extent can this principle be availed of? What range of pressure and what ratio of expansion should be assigned to a single cylinder? and how many cylinders should be adopted to give best results with the highest steam pressure practicable for a specified case? Common experience aids in solving this problem by showing that the very best results are ordinarily obtained, in each class of multi-cylinder engine, when, the engine being properly designed for its work, the terminal pressure for the system can be economically made something above the sum of back pressure in the low pressure cylinder, plus friction of engine. This total may be usually taken, probably, at about eight or ten pounds above a vacuum. The latter figure will be here assumed.

The fundamental principles are now easily perceived. There are three main facts upon which to base our theory of the multi-cylinder engine. These are:

(1) *Economical expansion in a single cylinder has a limit, due*

to increasing internal wastes, which is found at a comparatively low rotio of expansion.

(2) *The method of expansion may be, for practical purposes, such as are here in view, taken to be approximately hyperbolic; the terminal pressure being something above that which corresponds to the sum of all useless resistances, and which may be here taken, as, for example, about ten pounds per square inch above a vacuum. The division of the initial pressure by this terminal pressure will thus give an approximate measure of the* desirable *ratio of total expansion for the best existing engines.*

(3) *All steam entering any one cylinder will be rejected,* as steam,* *into the succeeding cylinder, external wastes being neglected, and into the condenser; and the full amount of steam condensed at entrance by absorption of heat by the interior surfaces of the cylinder will be re-evaporated later, and will pass into the condenser or into the next cylinder, and heat transferred in the one direction, in the one process, will be transferred in precisely equal amount in the opposite direction in the other.*

This last point is a very important one, and is very easily established. The cylinder, when in steady operation, is neither permanently heated or permanently cooled; no progressive heating can go on, as it would, in that case, become heated above the temperature of the steam and become a super-heater; no progressive cooling can occur, since, in that case, the cylinder would become a condenser of indefinite capacity. It must, therefore, transfer to the next element of the system all the heat which it receives, assuming that external radiation and conduction may be neglected and that the Rankine and Clausius phenomenon of internal condensation, by transformation of heat into work, is ignored. It also further follows that the introduction of one or of many cylinders between the terminal element and the boiler does not, through cylinder condensation, affect the operation of the latter cylinder, however great that condensation may be, provided the operation of

---

* This the writer would denominate Hirn's principle. See a paper by Dwelshauvers-Dery in the *Bulletin de la Société Industrielle de Mulhouse*, October, 1888, on the theory of single-cylinder engine.

the added elements is effected by raising the steam pressure commensurately, leaving the final element of the series the same initial pressure as before. The total waste by this form of loss is thus evidently measured, in the case of the multi-cylinder engine, by the maximum waste in any one cylinder. If all are equally subject to this loss, the rejected steam of re-evaporation from any one cylinder, as the high-pressure cylinder, supplies precisely what is needed to meet the waste by initial condensation in the next; and so on through the series. Thus the use of a series of cylinders, in this manner, divides the total waste for a single cylinder, approximately, at least, by the number of cylinders; and it is in this manner that the compound system gives its remarkable increase of efficiency. As stated by the writer, many years ago, "The serious losses arising from condensation and re-evaporation within the cylinder, and which place an early limit to the benefit derivable from expansion, affect both types of engine, and so far as seems now known, equally;"* but the modern type permits the interception of the heat wasted from one cylinder, for utilization by its successor, in such manner that the total waste becomes, practically, that of the low-pressure cylinder alone. If any one cylinder wastes more than another, the total waste is, as above stated, measured more nearly by the loss in the most wasteful member of the system.

Thus the three principles, which have been above enunciated, give a means of constructing a philosophy of the multi-cylinder engine, which will meet the essential needs of the designer and of the student of its theory. The first principle shows that a limit existing to economical expansion in a single cylinder, the advisable number of cylinders in series may probably be determined, when that limit is ascertained, either by experiment, by general experience, or by rational theory and computation. The second principle shows that we may find a tentative measure, at least, of the desirable total ratio of expansion for maximum density, when the best terminal pressure for the chosen

* Vienna Report, 1873.

type of engine is settled upon. This total range is divided by the admissible range for a single cylinder, or, perhaps better stated, the total ratio is a quantity which should approximately equal the admissible ratio for a single cylinder, raised to a power denoted by the number of cylinders. Combining thus the two considerations referred to, we obtain a determination, probably fairly approximate, of the proper number of cylinders in series. The third principle permits an estimate to be made of the probable internal wastes of the series, and the probable total expenditure of heat and of steam, and a solution of all problems of efficiency for the compound engine, of whatever type.

The first step in the process is evidently the determination of the best ratio of expansion, under the assumed conditions of operation and for the given type of engine, for a single cylinder; then the best ratio of expansion for the series, all things considered, this study being made from the financial standpoint, as must be every problem which the engineer is called upon to solve. It is not the thermodynamic, nor the fluid, nor even the engine efficiency, which must be finally allowed to fix the best ratio of expansion; but it must be the ratio of expansion at maximum commercial efficiency, that which will make the cost of operation at the desired power a minimum for the life of the system.* The total ratio being settled upon, and that allowable, as a maximum, for the single cylinder, it is at once easy to determine the best number of cylinders in series. The first-mentioned ratio is that at maximum commercial efficiency, as just stated; but the second must be taken as that which gives the highest efficiency of engine, the back-pressure in that cylinder and the friction of the cylinder taken singly, being considered, together with its proper proportion of the friction of the engine as a whole.

Studying the method of distribution of wastes among the several cylinders of the multi-cylinder engine, it will be observed that, since the pressures increase more rapidly

---

* See papers by the writer on the efficiencies of engines, as per references already given.

than the temperatures, the range of temperature in the high-pressure cylinder is greatest; while, the same weight of steam passing through the whole series, the low-pressure cylinder presents the largest area of condensing surface in proportion to steam used. These differences are to a certain extent, though not wholly, compensatory. It may be assumed, however, without serious error, that the necessity of applying jackets or other methods of reducing internal wastes, will apply substantially as imperatively to one cylinder as to another, and that the adoption of a common ratio of expansion for both or all cylinders, or of apportioning the ratios with reference to the equal division of power among them, will be found perfectly admissible and will introduce no serious avoidable loss. Authorities have greatly differed in their views as to the relative advantage of jacketing one or another cylinder; but it is at least safe to jacket all, and probably, as above indicated, best to do so. The importance of the jacket evidently becomes less as other expedients for reducing wastes of this kind are adopted and are made more effective; as by increasing speed of engine, by superheating, by reheating between cylinders; and cases may be imagined in which the jackets may cease to have sufficient value to justify the acceptance of the risks and expense incurred in their employment. The same is true of the more complicated forms of valve-gear needed to secure an approximation to the ideal distribution of steam.

The extent to which expansion may be economically carried in a single cylinder will vary somewhat with the initial temperature and pressure, and with the physical condition of the working fluid; but it may be taken as ordinarily not less than two and a half expansions for unjacketed engines with wet steam and three or four for the better class of engines. The total expansion ratio thus becomes, for several types of multi-cylinder engines, as below:

MULTI-CYLINDER ENGINES.

No. cyls.	*1.*	*2.*	*3.*	*4.*
r	2·5 to 3	6·25 to 9	16 to 27	40 to 81
p_1	25 to 30 lbs.	60 to 100 lbs.	120 to 300 lbs.	350 to 800 lbs.

Expansion is here assumed to be approximately hyperbolic, and the terminal pressure to be eight or ten pounds per square inch. General experience to date thus indicates that a triple expansion engine should do best work up to a pressure of about 250 or 300 pounds, and that the four-cylinder engine should be adopted from that point up to the highest pressures likely to be adopted in the steam-engine, the double expansion compound serving its purpose well below the lowest figures above assigned to the triple engine. Any of the four types of engine may be made to overlap the range assigned its labor by suitably providing against wastes occurring within the engine by increased speed, by superheating, by expedients giving higher effectiveness to the jackets, or other methods of improvement. Any system which increases the efficiency of the simple engine will improve the efficiency of the compound, and will correspondingly increase the range of pressure through which it will give satisfactory gain as compared with the former.

(*To be continued.*)

ON THE DILATATION AND COMPRESSIBILITY OF WATER AND THE DISPLACEMENT OF ITS MAXIMUM DENSITY BY PRESSURE.*

BY E. H. AMAGAT.

Translated by Chief Engineer ISHERWOOD, U.S.N.

I have described in a preceding communication (*Comptes Rendus*, August 23, 1886), the method I adopted for the determination of the dilatation and compressibility of liquids under very high pressures, and I gave some of the results obtained, but not corrected for the deformation of the piezometers. The ascertainment of this deformation, which I am now engaged on, appears so long and difficult, that I think I should without delay make known the results I have obtained for water, which has a special interest because of its phenomenon of maximum density.

* *Comptes Rendus*, 1887, p. 1159.

Mr. Tait, who, previously to me, investigated water between wide limits of pressure, has given for that liquid the following formula:

$$\frac{v - v_0}{p\,v_0} = 0{\cdot}0000489 - 0{\cdot}00000025\,T - 0{\cdot}0000000067\,p$$

applicable between 6° and 15°, and between 150 and 500 atmospheres, but I believe that no physicist up to the present time has examined the subject relative to the maximum of density.

The method I employ gives directly the pressure necessary to maintain a constant mass of water at the same volume at all temperatures, consequently, if with two different temperatures the same pressure is obtained, there must lie between them, as regards that pressure, the temperature corresponding to the maximum of density. The use of the same pressure with the different temperatures obviates the necessity of correction for the elasticity of the material of the piezometer, for the calculation of which the data are still wanting. The correction for difference of temperature relative to the dilatation has been made by provisionally admitting that the coefficient of dilatation of glass does not vary with the pressure, a supposition which cannot cause any notable error, inasmuch as in the present case the variation of temperature is only of a few degrees.

As regards pressure, I have carried my experiments on water up to 3,200 atmospheres; and as regards temperature, I have operated between zero and 50°, with the following results:

At 200 atmospheres, in round numbers, the maximum density of water retrograded towards and nearly reached zero. It appeared to be between zero and 0·5° (half a degree).

At 700 atmospheres there was no longer any maximum of density above zero, the form of the curves indicating clearly that it had passed below zero; further, the investigation could be followed to still lower temperatures since the freezing point of water is lowered by increased pressure.

To well understand the *ensemble* of the phenomena and

the resulting consequences, curves should be formed by taking the pressures as abscissas and the volumes as ordinates, to represent at different temperatures the volumes occupied under all the pressures by the same mass of water. These curves intersect each other successively at points which correspond to the change of the sign of dilatation of the water, and fall successively in the order of the temperatures, the pressure increasing. At 200 atmospheres they are in the normal order, becoming more and more closed or straightened as they correspond to lower temperatures. The pressure constantly augmenting, they become more and more opened in such a manner that the co-efficient of dilatation increases rapidly at first, and then more slowly with the pressure, which is just the contrary of what takes place with all the other liquids I have examined. Towards 3,000 atmospheres the co-efficient of dilatation ceases to increase, and under greater pressures it probably diminishes as in the case of other liquids; the effect, too, is much less marked as the temperature, with equal pressure, is higher.

There results, likewise, from this disposition of the curves that, between two different pressures, the difference of the ordinates and consequently the co-efficient of compressibility diminishes when the temperature increases, which is also contrary to what occurs in the case of other liquids, a fact long since shown by Grassi, and a quite natural result of the disappearance of the maximum of density. Furthermore, and for the above reasons, this diminution of the co-efficient of compressibility disappears when the pressure increases, and it also disappears when the temperature increases, conformably to the results of Messrs. Pagliani and Vicentini, according to whom the compressibility of water ceases to decrease above 50°. The temperature at which this inversion takes place decreases when the pressure increases.

Generally, a sufficient increase of pressure or of temperature gives water a tendency to conform to the ordinary case of liquids; and towards 3,000 atmospheres the last traces have disappeared of the perturbations of the general law which result from the existence of maximum density.

Such are the general results of the *ensemble* of the phe-

nomena. I shall continue the study in detail, and investigate the subject below zero. I can give the definitive numerical results only after I have finished the work now in progress on the deformation of the piezometers.

In conclusion, I would add that none of the liquids I have studied up to the present time, has shown a maximum of density under any pressure, which is contrary to a prevision formulated recently by Mr. Grimaldi, based on assumed constancy of the co-efficient of compressibility within wide limits of pressure, an assumption in complete disaccord with the results I have obtained with all the liquids I have investigated.

RESEARCHES ON THE SPHEROIDAL STATE OF WATER.*

By Mr. Gossart.

Translated by Chief Engineer Isherwood, U.S.N.

The results which I have the honor of presenting to the Academy, are relative to the temperature of water in the state of calefaction under decreasing pressures comprised between 760 millimetres and 0·5 millimetre.

Recently, Mr. Luvini (*Il Nuovo Cimento, t. xvii*) has published some researches on the temperature of water, of alcohol, and of ether, calefied in a vacuum, but he could not maintain constant the temperature of the crucible containing the liquid and merely resting on a brick heated under a glass bell. Forming the vacuum rapidly, he followed the simultaneous change of a thermometer placed in the liquid, and of the pressure. From his observations he concluded that *the temperature of the liquid spheroid is the same as the temperature of ebullition under the pressure in the enclosed space* and that there could be thus directly caused the freezing of water, but there cannot be affirmed, particularly as the crucible is not taken out and is still very hot, that the liquid has not ceased to be in the spheroidal state.

* *Comptes Rendus*, 1887, page 1270.

I have sought to verify the relation indicated by Mr. Luvini, but maintaining constant the temperature of the crucible, the volume of the liquid, and the pressure, in order to measure with certainty the data of the experiment.

A copper plate is raised at its centre in the form of a truncated cone, the upper base of which is a concave plate of 0·04 metre diameter and 0·01 metre depth, brazed on. The plate is turned up around the base of the cone so as to form a kind of box in which a current of cold water is circulated. Inside the truncated cone and above the plate is a lighted gas-jet, placed there to heat the upper base which contains the liquid.

Around the plate is a circular gutter or groove in which is cemented by marine glue a glass bell having two tubulures. Through the central tubulure is passed a mercurial thermometer having a flat bulb so that it may be immersed in the liquid or drawn out to remove it from the radiation of the crucible.

The lateral tubulure is traversed by the tube for making the vacuum and by another and narrower tube for conducting the liquid that feeds the drop. With a Carré machine the vacuum is produced at the same time in the glass bell and in the flask containing the supply of liquid.

A large tube of lead traverses the bottom of the plate, and leads the small drops accidentally thrown and the vapor into a large cold balloon containing sulphuric acid. From the neck of the balloon go tubes to a barometric manometer, and to a trumpet with a tubulure for the entrance of air or the introduction of any gas. By sealing with water all the stoppers and joints I have been able to maintain, for over twenty-four hours, a pressure of less than one millimetre.

The following are the results obtained with distilled water for pressures comprised between 760 millimetres and 0·5 millimetre:

(1) Below 33° the temperature of the liquid is higher than the temperature of its ebullition under the pressure in the surrounding space.

(2) From 33° to 50°: the difference between these two temperatures is very feeble, sometimes nothing, and not

surpassing 0·5° at most; it is sometimes positive and sometimes negative.

(3) Above 50° up to 90°—the last temperature I observed—the temperature of the drop is constantly less than the temperature of ebullition under the same pressure. Mr. Boutigny obtained 97° for the temperature of calefied water under the pressure of 760 millimetres.

(4) While for the low temperatures the differences increase regularly enough between 0° and 30°, yet above 50° the differences, though always preserving the same sign, do not appear to vary as regularly. This is a point to which I propose to return.

These conclusions are warranted by the following experimental results:

Pressures in Millimetres.	*Temperature of the Liquid Calefied.*	*Temperature of Ebullition.*	*Differences.*
2	0°	—12°	+ 12°
8	15	8	+ 7
21	24·5	23	+ 1·5
35	32·25	31·8	+ 0·45
48	37·5	37·5	0
83	48	48	0
138	58	58·5	— 0·5
152	60	60·5	— 0·5
241	70	70·8	— 0·8
341	78	79	— 1
567	90	92	— 2

In carrying the rarefaction to the extreme limit of 0·5 millimetre, I have seen a drop of water, of at least two grammes, become, notwithstanding the high temperature of the crucible, first opaque, and then a rounded piece of solid ice, which remained during more than a quarter of an hour rocking gently on the crucible, which was always kept heated by the gas-jet. I thus realized the experiment imagined by Mr. Luvini, but not realizable by the method he employed.

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, November 19, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 19, 1889.

MR. T. C. PALMER, Vice-President, in the Chair.

Members present: Prof. R. L. Chase, Mr. A. T. Eastwick, Mr. Lee K. Frankel, Mr. F. Lynwood Garrison, Mr. Reuben Haines, Prof. L. B. Hall, Dr. H. W. Jayne, Dr. H. H. Keller, Mr. F. C. Lewin, Mr. Otto Lüthy, Mr. W. W. McFarlane, Mr. W. L. Rowland, Prof. S. P. Sadtler, Prof. Edgar F. Smith, Prof. N. Wiley Thomas, Dr. Wm. H. Wahl, Mr. L. E. Williams and two visitors.

The following gentlemen were elected to membership in the Section: Mr. Geo. L. Norris, Pencoyd, Pa.; Mr. Hugh A. Galt, 1011 Spruce Street, Philadelphia; Mr. Lucius E. Williams, Swarthmore College, Swarthmore, Pa.; Mr. Hermann Schanche, Gray's Ferry Chemical Works, Philadelphia.

Dr. Jayne asked for information on By-Law IV regarding the dropping of delinquent members. The question was as to the necessity of action on the part of the Section in such cases. It was decided that no special action of the Section was necessary, but that delinquent members shall, at the proper time, simply be dropped from the list; in accordance with this decision, the Treasurer notified the Secretary to drop the names of two delinquents from the list.

The nomination of officers for the ensuing year was then taken up. The following nominations for President were made: Mr. T. C. Palmer, Prof. S. P. Sadtler, Prof. R. L. Chase. On motion, the nominations for President were closed.

Nominations for two Vice-Presidents were then made. The following gentlemen were put in nomination: Dr. H. H. Keller, Mr. W. L. Rowland and Prof. Henry Trimble. On motion, the nominations for Vice-Presidents were closed.

Dr. W. C. Day was nominated for Secretary, Dr. H. W. Jayne for Treasurer, and Dr. Wm. H. Wahl for Conservator.

Mr. W. W. McFarlane gave a description of some new dyeing materials, in which he explained the use of a number of dyes which have recently been introduced into this country by the representatives of Fried. Bayer & Co., of Elberfeld; samples of dyed products were also exhibited.

Among other interesting matters, the speaker stated that "carmine blue" is dyed with the use of Glauber's salt and sulphuric acid, in the same way as indigo carmine or extract, and further, that the carmine blue will probably displace the indigo extract at no distant period in the future. "Sulphon Azurin" is also used in dyeing cotton, using a boiling bath and some alkaline salt, such as borax, sal-soda, sodium phosphate or silicate. The blue produced is similar in shade to that of indigo, and is said to withstand the action of light and of dilute acids as well.

Benzo-black-blue is dyed in cotton in the same way as other benzo colors, and very dark shades are the result. There are two shades of this color, designated respectively as G and R.

The paper was discussed by Messrs. McFarlane and Palmer. Dr. Wahl, from whom a paper was expected, announced that he must defer, until a later meeting, his paper on "a new gold-like alloy;" and gave in place of this, a statement of further results obtained by him in the electrolytic deposition of platinum, exhibiting specimens of work. As the investigation is not yet entirely completed, and certain details of the mode of procedure are to be made the subject of letters-patent, the speaker preferred, for the present, to withhold the same from publication. Dr. Wahl also made some critical remarks on statements made in a paper by A. J. Rogers, on "Experimental Researches in the Reduction of the difficultly-reducible Metals," which was published in the *Proceedings of the Wisconsin Natural History Society*, April, 1889, expressing doubts, based on theoretical considerations, as to the accuracy of one of the results announced by the author; namely, that he had obtained "a yield of aluminium six times greater than had ever been obtained by electrolysis."

Mr. F. Lynwood Garrison presented some remarks on the Paris Exposition, with special reference to Metallurgy and Fuels. As these remarks will be embodied later on in a full and comprehensive report to the INSTITUTE, they are omitted here; this paper was followed by a general discussion of some of the statements it included.

Prof. E. F. Smith read a paper on the occurrence of vanadium in caustic potash. This paper was referred for publication He then presented another on the subject of nitration by the use of nitrogen trioxide as obtained by the action of nitric acid on arsenic trioxide. This paper was also referred for publication.

Professor Smith next presented the following results of further work in the electrolysis of metallic sulphocyanide solutions. His object in presenting these results was to reserve for the future the field upon which he has entered. In addition to the results already reported in a former paper, it was observed that iron, cobalt and nickel in sulphocyanide solutions were fully deposited by weak currents, and that the presence of a sulphocyanide in manganese solutions prevented the formation of the dioxide, and when the latter had

already precipitated the addition of KCNS would effect its re-solution. To these facts may be added that mercury, cadmium, bismuth and lead deposit from sulphocyanide solutions. With lead, a behavior analogous to that noted with manganese was observed.

Approximate quantitative separations were made in several cases, but the complete development of these observations requires further study. Another line of experiment has been the electrolysis of metallic phosphates in the presence of free phosphoric acid. Mercury, silver, copper, cadmium, lead, iron, zinc, cobalt, and manganese have given interesting results qualitatively, and quantitatively. Separations seem possible when regard is had to the proper condit on of the current. The speaker stated that although in possession of quantitative figures in some of these cases, he preferred to postpone their publication until a careful examination has been made with each metal. Curiously enough, with manganese phosphate dissolved in phosphoric acid there is no separation of dioxide; the solution slowly acquires a red tint, and in time becomes turbid, although the addition of more acid causes the turbidity to disappear.

Dr. Warwick, at the request of Professor Smith, has begun an electrolytic study of the metallic formates; the results obtained will be communicated later.

Adjourned. WM. C. DAY, *Secretary*.

EXPERIMENTAL RESEARCHES IN THE REDUCTION OF THE DIFFICULTLY-REDUCIBLE METALS.

By A. J. Rogers.

[*Reprinted from the Proceedings of the Wisconsin Natural History Society, April, 1889.*]

This pamphlet of eighteen pages gives the result of experiments made by the author, upon the reduction of sodium and of aluminium from their salts, by electrolysis, at a high heat. The experiments are carefully made, giving proportions of raw materials, strength of current, time employed, and practical results as compared with the theoretical. The author gives first a *résumé* of some conclusions arrived at in a paper by him, read before the American Association for Advancement of Science, at Ann Arbor, in 1885, in which among other points established, he finds that from fused sodium chloride, 61 per cent. of the theoretical amount of sodium is reduced by electrolysis; this being the average result of six experiments. It thus seems that with suitable apparatus from 5 to 6 pounds of Na could be produced in 24 hours to one electrical horse-power, thus, if there were no practical difficulties in the construction of crucibles and other apparatus involved, nor in working continuously on a large scale with a raw material so cheap and pure as NaCl, the metal could be obtained at a small cost and could be applied to the reduction of other difficultly-reducible metals, including that very valuable metal Al.

He next turns his attention to the alloys of sodium with lead, and also with tin. He finds that "they can be heated to a higher temperature than pure Na or K, in acid (silicious) crucibles, without the Na or K attacking the crucible."

Description of the properties of the sodium-lead alloys are given: the proportions of the two metals varying from 1 part of sodium with 9 parts of lead, up to 1 part sodium with $1\frac{5}{6}$ parts lead. These richer alloys can be cut with a knife, like sodium, and act very rapidly when thrown upon

water. The same properties are peculiar to the sodium-tin alloys.

These alloys are formed by passing a current through melted NaCl in crucibles containing lead or tin serving as a cathode.

A series of nine experiments are reported, in most of which, however, cryolite was mixed with the salt. A small amount of aluminium was in all cases reduced, which was separate mostly from the lead- or tin-sodium alloy. But the principal yield of Al was obtained by heating the sodium alloy with cryolite afterwards in another crucible. It may be interesting to cite a part of one experiment.

"*Experiment 8.*—Passed 80 ampères with 24 volts through four crucibles in series, for six hours, using 1 part of cryolite to 3 parts of NaCl with 450 grains lead in each crucible. * * * Two hundred and fifty grains of quite pure Al was obtained, with a large amount of Na in the remelting with cryolite. There was then actually obtained, besides all losses, in round numbers, 1 pound of Al to the electrical horse-power per day of 24 hours.

"Probably 8 to 10 per cent. can be obtained from cryolite, where the theoretical yield is 12·85 per cent.

"The best results, and, in fact, the only quantitative results that have yet been published, so far as I am aware, for the separation of Al by electrolysis, are reported by Dr. John Hopkinson, of the Kleiner process, where 3 grains were produced to the electrical horse-power per hour, which would be about one-sixth of a pound in 24 hours."

Mr. Rogers' results may be summed up as follows:

(1) The formation of a rich alloy of lead or tin with sodium, by electrolyzing common salt at a high heat, in presence of lead or tin.

(2) The reduction of aluminium from cryolite, or from the double chloride of aluminium and sodium, by simple heating with the above sodium alloy.

(3) A yield of aluminium, six times greater than has ever been obtained by electrolysis.

His paper is well worth the attention of all metallurgists.

P.

ACTION OF THE GAS FROM As_2O_3 AND HNO_3 UPON *p*-OXYBENZOIC ACID.

BY EDGAR F. SMITH.

[*Read at the Stated Meeting of the Chemical Section, November 19, 1889.*]

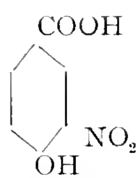
In vol. viii, p. 99, of the *American Chemical Journal*, I called attention to the fact that when methyl salicylate, in ethereal solution, was exposed to the gas arising from arsenic trioxide and nitric acid, ethers of α and β-meta-nitro-salicylic acids were produced. This procedure gave a ready method for the production, as well as an easy means of separating these two acids, the ether of the α-acid being readily soluble, while that of the β-acid was practically insoluble in ether.

The ethyl ether of meta-oxybenzoic acid, in ether, gave when acted upon as above ethers of β-nitro-meta-oxybenzoic acid (m. p. 230° C.) and trinitro-meta-oxybenzoic acid (m. p. 111° C.). The details of this investigation may be found in the *Proceedings of the American Phil. Soc.*, September 7, 1888. I have recently experimented in the same line wih *p*-oxybenzoic acid. The starting point was ethyl para-oxybenzoate, prepared according to the recommendation of Hartmann in the *Journal fur praktische Chemie* [II], **16**, 50. The ether thus obtained, after crystallization from water, gave the constant melting point 112°·5 C., as stated by Graebe (*Annalen*, **139**, 146), and not 116° C., as given by Hartmann. The pure ether was next dissolved in ordinary ether, and the solution then acted upon for one and one-half hours, in the cold, by the vapors from nitric acid and arsenic trioxide. The flask containing the ethereal solution was corked and allowed to stand in a cool place for several days, after which the ether was distilled off. The residue was dark and oily, but after several hours became solid and crystalline. By solution in hot alcohol and recrystallization long, stout, red-colored needles were obtained. These melted regularly at 69°–70° C. Barth (*Journal für prakt. Chemie*,

100, 369), speaking of the action of nitric acid upon ethyl *p*-oxybenzoate mentions two products, ethyl nitroparaoxybenzoate and ethyl dinitroparaoxybenzoate. His description of the mononitro-ether is so meagre that I was not able to determine at first whether I was dealing with a well-known compound or an entirely new product. The subsequent analysis of the free acid left no doubt as to the identity of my compound and that described by Barth. This chemist remarks that the melting point of the nitro-ether lies below — 100° C., I have found it as above —69°–70° C. On boiling the ether with caustic potash for some time and then acidulating the alkaline liquid a crystalline mass separates. It dissolves readily in hot water, crystallizing from it, on cooling, in long needles with a faint yellow color. At times the needles showed a flesh-red color; this was removed by boiling the aqueous solution with animal charcoal. When pure the acid melted at 184°–185° C., the same as the acid obtained by Barth. A nitrogen determination, made by Mr. Seal of this laboratory, gave 7·95 per cent. N. The required N for a mononitro-*p*-oxybenzoic acid is 7·65 per cent.

An attempt to estimate the nitrogen in the ether by the Kjeldahl method, failed.

Griess (*Berichte*, **20**, 480) also obtained nitro-*p*-oxybenzoic acid of melting point 185° C., and showed that it was identical with the acid he had previously prepared from *p*-amidonitro-benzoic acid by boiling with KOH, so that its constitution and that of the acid prepared by me as above described is undoubtedly



Hasse (*Berichte*, **10**, 2,188) states that nitro-*p*-oxybenzoic acid contains water of crystallization. The acids of Barth, Griess and myself are anhydrous.

While *p*-nitro-oxybenzoic acid requires a large volume of

hot water for its solution, its sodium salt is very soluble, and from its concentrated liquid separates in beautiful red colored needles forming bundles.

The amide of the acid ($C_6H_3(NO_2)OH.CONH_2$) consists of beautiful orange-yellow colored tufts. It melts at 160°–161°, and dissolves easily in hot alchohol.

The above account concludes my study of the action of the vapors from nitric acid and arsenic-trioxide upon the three hydroxy-benzoic acids. The results briefly summarized are these:

With ortho-oxy-benzoic acid two nitro acids were obtained; with meta-oxy-benzoic acid one nitro acid and a tri-nitro-meta product resulted, and with para-oxy-benzoic acid one meta-nitro acid.

The course of the reaction in these three cases (the *m*-oxy-acid excepted) was not attended by any troublesome intermediate products, and for this reason the method may perhaps become serviceable in the nitration of other oxy-acids.

CHEMICAL LABORATORY OF THE UNIV. OF PA.,
PHILADELPHIA, November 18, 1889.

VANADIUM IN CAUSTIC POTASH.

BY EDGAR F. SMITH.

[*Read at the Stated Meeting of the Chemical Section, November 19, 1889.*]

The occurrence of vanadium in commercial caustic soda has been noticed (See Baumgarten, *Zeitschrift für Chemie*, 1865, **605**, and Donath, *Zeitschrift für Analyt. Chemie*, **21**, 45). As far as I am aware, it has not been observed in caustic potash, hence the following lines.

While engaged in making certain decompositions, for which I employed the ordinary stick potash, I was rather surprised, after saturating the alkaline solutions with hydrogen sulphide, acidulating with hydrochloric acid, and heating for several hours, to discover that the separated sulphur showed a decidedly chocolate-brown color. This occurred

repeatedly. The quantity of dark material was never very great, yet it was present, even in potash from alcohol. Some preliminary experiments were made which pointed to vanadium. I therefore saturated the warm aqueous solution of three pounds of stick potash with hydrogen sulphide. Heat was applied for several hours longer, and during this period the liquid gradually assumed a yellow to deep red color. Hydrochloric acid was added to distinct acid reaction. The separated sulphur was quite dark in color. After filtration and washing, the residue was dried and treated with carbon disulphide to extract the free sulphur. The chocolate-colored mass remaining after this treatment dissolved, with exception of a slight quantity, in yellow ammonium sulphide, from which it was reprecipitated by dilute acid. Again washed, treated with carbon disulphide, and carefully ignited, there remained a crystalline mass. With a small quantity of this last product I made the phosphorous bead test—yellow, passing through dark to green when cool. Another special test consisted in dissolving a portion of the ignited residue in a drop of conc. sulphuric acid, free from iron. One cc. of water was next added, and to this colorless solution from one to three drops of a dilute potassium ferrocyanide solution, whereupon the liquid acquired a fine green coloration. This latter test Dr. Walz (*American Chemist*, vol. vi, p. 453) employed in detecting the minute quantities of vanadium in American magnetites. He considers it conclusive evidence of the presence of vanadium. The most important test, and that which I applied to the remainder of the ignited residue, after effecting its solution in nitric acid, was to add a large piece of ammonium chloride to the ammoniacal solution. The morning following, crystals of ammonium vanadate had separated. These gave the true vanadium bead, and when ignited, moistened with pure, strong nitric acid and evaporated, left the deep red-colored residue characteristic of vanadium compounds.

The vanadium sulphide, as first obtained, was impure, consequently the reactions were at times masked, and it was only after eliminating some silver and iron that the reactions were unquestionable.

The impure sulphide from the three pounds of caustic potash weighed about one-half gramme.

CHEMICAL LABORATORY OF THE UNIV. OF PA.,
PHILADELPHIA, November 18, 1889.

NOTES AND COMMENTS.

CHEMISTRY.

NEW PHOTOGRAPHIC DEVELOPERS.—*Eikonogen*, introduced but a few months ago by Dr. Andresen, of Berlin, as a developing agent for dry plates and bromide paper, seems to have grown into favor with more extended tests and to justify in a high degree the expectations formed. The following are the most prominent facts of its current literature, already quite extensive. Chemically it is the sodium salt of amido-β-naphthol-β-sulphonic acid, having the symbol

$$C_{10}H \left\{ \begin{array}{l} SO_3Na \\ OH \\ NH_2 \end{array} \right.$$

The formulæ for its use, as well as its action, are closely analogous to those of hydroquinone. The deposit formed by it is, however, said to be finer and of a very delicate bluish-black color, thus bringing out all the finest details. By some hydroquinone is regarded as giving stronger negatives, all things being equal, but the eikonogen as giving better half shadows, and consequently better for portraiture than for landscape photography. It is said to be particularly well adapted for lantern slides and line work negatives; and in spectroscopic photography it seems as sensitive as pyrogallol in giving the shades of depth corresponding to variation in brightness of the spectral lines, and at the same time to give a picture with blacker lines, more easily seen under the microscope.

For bromide paper, according to General Brown, it is undoubtedly the developer of the future, affording warmer tones than the oxalate, and beautifully clear whites, without acid flushing, with simple rinsing with water before fixing. Whilst the appearance of the picture is slow, especially as a used developer, preferably twenty-four hours old, is preferred, the development is regular and uniform to every detail, without risk of staining; and the same solution can be used for a number of prints. It is said to be unaffected in its action by variation in temperature, and therefore adapted to all climates. It is non-poisonous; does not stain the fingers; will keep over a month mixed; acts so energetically that only half the exposure is required as that with pyrogallol, and development occupies a much shorter time. The solution can be used over and over again without staining until its reducing power is exhausted. It is, on the other hand, especially adapted to development of over-exposures. With all its excellencies it is a cheap developer, and will keep indefinitely as a dry powder. Its slight solubility, however, will prevent its use in concentrated stock solutions, as pyrogallol.

The commercial article is accompanied by formula for its use, and the recommendation by some to reduce the strength of these does not seem to be approved by the most successful experimenters with it. The following formula, by General Brown, for a normal developer, will serve to indicate the general character of solutions used.

Solution I.—Sodium sulphite, 15 grains; eikonogen, 7½ grains; water, 1 ounce.

Solution II.—Carbonate of potassium, 80 grains; water, 1 ounce.

For use mix with three parts of I, one-half to one part of II, according to exposure.

Pyrocatechine.—Orthodihydroxybenzol, an isomer of hydroquinone, with the formula $C_6H_4(OH)_2$ is at present a subject of careful investigation as a developing agent for dry plates. The results thus far are quite promising. Its use as a photographic developer was suggested as early as 1859 by Wagner. Eder and Toth announced its developing power in alkaline solution in 1880. Professor Benoist, of Tolouse, last year published results of considerable experience with it. Dr. Arnold pronounces it fifteen times as energetic as hydroquinone, and enumerates among its chief excellencies, the excellent tone and good qualities of the negatives produced by it; the absence of fog; loss of sensitiveness to light of the plates after immersion in the developer, so that development may be continued after immersion in ordinary gaslight, or even in diffused daylight without injury; great latitude of exposure as development proceeds slowly, but uniformly; freedom from stain to the hands; simplicity of formulæ for solutions, and possibility, on account of its solubility, of preparing concentrated stock solutions which will keep well if the pyrocatechine is chemically pure, and which can be used by the drop; convenience in carrying the small quantities of ingredients required for development; development without motion; and withal, on account of its high reducing power, the expense, at twenty-five cents per gramme, is not exorbitant, as that quantity will develop 100 to 150 plates 13 x 18 cm. He employs the following stock solutions; *a*, one per cent. solution of pyrocatechine; *b*, twenty per cent. solution of potassium carbonate. Sodium carbonate he does not find to answer as well. For development of a well-exposed plate, 7 x 9 inches, one cc. of *a* and 5 — 10 cc. of *b* are mixed with 60 — 80 cc. of water. Sulphite of soda does not seem necessary or desirable. The mixed developer will not keep, and should be used only once. Carl Irna, employing it with carbonate of soda and sodium sulphite, as in Balagny's formula for hydroquinone, found it more energetic than the latter, whilst others have found it less so. Dr. Eder in his more recent experiments was particular to employ it in its purest form, as was Dr. Arnold, and found it a rapid, energetic developer, yielding coffee-brown negatives of good quality. He employed the following solutions: *A*, pyrocatechine 1 part, sulphite of soda 4 parts, water 40 parts; *B*, carbonate of potash 4 parts, water 40 parts, mixing for use one volume of *A* with two of *B*. The sulphite of soda is not absolutely necessary, but with it the solution will keep clear much longer.

Paraphenylendiamin—$C_6H_4(HN_2)$, has been found by Dr. Eder to act well as a developer for dry plates, having about the same energy as pyrogallol or hydroquinone. As far as experiments have been conducted, the development with it is regular, and negatives produced are delicate and soft. It was used with potash, without sulphite, which retards the development greatly, but prevents the solution from becoming colored. C. F. H.

BOOK NOTICES.

HINTS ON HOUSE BUILDING.—Some desultory notes in popular form, mostly reprinted from *The Mechanical News*, by Robert Grimshaw, author of, etc. Second and enlarged edition. Practical Publishing Company, New York.

This is a small book with a very long title. It makes no pretension to fine writing, but deals in practical suggestions. Directions are given for the proper choosing of sites for building, correct modes of construction, interior arrangements, etc. What is said *inter alia* respecting ventilation, dimensions of rooms, roofs, correct and safe construction of flues and the notes on heating should commend it to the attention of all desiring healthy and convenient homes. The booklet is dedicated "to those who board, and to those who inhabit flats and are able to do better," *i. e.*, to build homes; it is a very good argument throughout that every man should become a house-owner. N.

A TREATISE ON STEAM-BOILERS. By Robert Wilson, C.E. Enlarged and illustrated from the fifth English edition by J. J. Flather, Ph. B. New York. John Wiley & Sons. 1889. pp. 36a, 437.

This well-known book has lost nothing by its treatment in the hands of its American editor. It has for years been the best work on the subject of steam-boilers and only needed the details of American practice to make it invaluable. These details have to a great extent been added in the present edition. It is a matter of regret that the additions were not made in the body of the text, but were added in the shape of an introduction and an appendix. The introduction is to some extent historical, as cuts are given of spherical, haystack and wagon boilers, after which are given many of the more modern forms, but omitting entirely the marine type. Fair examples of the plain cylinder, flue, tubular, Lancashire and Galloway boiler are described, and the various vertical and sectional are shown, the introduction furnishing a fairly satisfactory groundwork on which to begin the study of the design. After the introduction is given the text of the English edition with practically no changes. This part of the work could easily have been made more satisfactory to the American reader by replacing the commercial names used by their equivalents, which are more familiar in this country, and bringing the text to date. The use of corrugated furnaces is spoken of as something simply proposed, instead of having been in use now for a number of years. The use of steel is spoken of as something comparatively rare. As this part of the text is entirely English, it would not have been amiss to have at least

stated the brands of American irons and something of their relative properties. A few errors have been carried along from one English edition to another and appear in this one, the most noteworthy one being for the thickness of a sheet between two series of stays, in which

$$\frac{w\,l}{2} = c\,b\,d^2$$

is given as the strength of a rectangular beam, l, long, b, broad, and d, deep; w being the load uniformly distributed, and c the strength of the material, the beam being fixed at the ends.

The appendix supplements the text very nicely, as it answers many of the questions a beginner would ask. Figures showing many of the details of bracing are given, and many of the boiler attachments, such as safety valves, fusible plugs, gauges, water columns, grate bars and sediment collectors are shown by examples of the most approved forms. The inevitable steam-boiler explosion pictures are shown, including the picture of the explosion of the vertical boiler which first (?) appeared in the *Scientific American* in 1882, and in nearly every book and paper on the subject since. While figures showing the running gear of an agricultural boiler after an explosion, and the trajectory of a boiler which started from a third-story window and landed a few squares away, and apparently illuminated the houses it passed over, may be of considerable interest, they are entirely out of place in a work of this kind.

Numerous tables are given in the appendix, which are of considerable value, among others the values of American coals, standard dimensions of boiler tubes, ratio of heating surface to horse-power and grate, factors of evaporation, and Kent's chimney tables. Taken as a whole, the work is in a more satisfactory shape than in the English edition, but might be even better adapted to the needs of the American reader. H. W. S.

THE GARDEN OF EDEN. The allegorical meaning revealed, etc. One of the numerous lectures delivered by Mrs. Victoria Claflin Woodhull, in the principal cities throughout the United States.

This composition is of the class which takes an idea, more or less important, and proceeds to run away with it and make it a universal key to all that is mysterious in life. Such an idea (with due deference to Mr. Donnelly) was that of making the roughly-printed old folios of Shakspere, with their clumsy typography, contain a cipher of unparalleled intricacy. Such are the interpretations of prophecy worked out of the Scriptures from time to time, and made to indicate either the end of the world, or the identity of some man who has made himself prominent with the antichrist. These amusements are harmless enough, and seem inseparable from the life of even civilized man. They amount simply to ingenious exercises requiring the term of the prophecy they interpret to disprove the solution. This lecture, however, though the same in general scope, is different from the harmless crazes above alluded to, inasmuch as it gives evidence of having been conceived in a brain addicted

to salacious introspection. All the professions of high-toned virtue with which the pamphlet abounds, do not suffice to mitigate its distinctly unclean influence. The interpretation of the meanings of the words Pison, Gihon, Hiddekel and Euphrates, the four branches of the river which went out of the garden of Eden, is somewhat ingenious but very far-fetched indeed. The Garden of Eden is the abdominal cavity, whence the river branches into "Pison," the circulating blood; "Gihon," the stream which carries off the waste solid residues; "Hiddekel," which performs the same function for the liquids, and "Euphrates," which "flows through the reproductive system." This is an excellent pamphlet to omit from the shelves of a library of useful books. F.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, November 20, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
WEDNESDAY, November 20, 1889.

JOSEPH M. WILSON, President, in the Chair.

Present, fifty-four members and ten visitors.

Additions to membership since the previous meeting, forty-six.

Mr. WM. L. BOSWELL, one of the delegates of the INSTITUTE to the late Universal Exposition in Paris, presented an oral report on the subject of "The Fire Defences of Paris, as Compared with those of American Cities, and especially of Philadelphia." The speaker discussed the theme at some length, and presented an instructive contrast of conditions and usages in vogue in the two countries. The subject was illustrated graphically. It was freely discussed by Messrs. FULLERTON, WEAVER, WIEGAND and BOSWELL. Mr. BOSWELL'S report will appear in the JOURNAL.

The President made some remarks upon his observations of trade schools in France and England, having been charged with the task of investigating the organization and mode of operation of such institutions on behalf of the projected school of Mr. A. J. DREXEL, of this city. The President proposed to make this theme the subject of an elaborate report, for early publication in the JOURNAL.

Mr. W. N. JENNINGS exhibited, with the aid of the lantern, a series of photographic views, taken along the line of the Pennsylvania Railroad, shortly after the disastrous floods of last spring, that proved so destructive of life and property. The pictures embraced views showing the break in the South Fork Dam, the remains of the well-known Conemaugh Viaduct, and of wrecks of a number of locomotives and trains.

The Secretary presented his usual report of technical progress, and the meeting adjourned. WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR OCTOBER, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, October 31, 1889.

TEMPERATURE.

The mean temperature of fifty-nine stations for October, 1889, was 47°·2, which is about 4° below the average, and 1° above the month of October, 1888. The means of the daily maximum and minimum temperatures, were 57°·3, and 37°·3, respectively. These give a mean temperature of 47°·3, and an average daily range of 20°·0. The stations that recorded the highest temperatures during the month were Coatesville, 83°; Annville, 82°; West Chester, 80°; Lancaster, 80°, and Westtown, 80°. These occurred on the 12th.

The lowest were Wellsboro, 13°; Dyberry, 14°; Columbus, 14°, and Phillipsburg, 14°. These occurred on the 24th, and are 3° below the coldest temperatures generally reached in October.

Total deficiency in temperature during October, at Pittsburgh, 103°.

Total deficiency in temperature during October, at Philadelphia, 110°.

Total excess in temperature since January 1st, at Pittsburgh, 90°.

Total excess in temperature since January 1st, at Philadelphia, 222°.

BAROMETER.

The mean barometer for the month, 30·08, is slightly above the average. The highest pressure occurred on the 23d, and the lowest on the 1st and 27th.

The extreme range was about nine-tenths [·9].

PRECIPITATION.

The average rainfall for the month was 3·85 inches, which is nearly normal. There was a small excess in the eastern portion of the State, and a small deficiency in the western.

The largest totals in inches were Eagles Mere, 8·61; Reading, 5·74; Drifton, 5·74; Wellsboro, 5·61; Westtown, 5·73; Swarthmore, 5·29, and Quakertown, 5·23.

General rain-storms took place on the 1st, 6th, 12th, 13th, 14th, 22d, 23d, 26th, 27th, 28th and 31st.

The heaviest rainfall during the month was on the 27th.

There was a heavy hail-storm in several sections on the 1st, and the first general snow occurred on the 23d. The quantity that fell was small and soon melted.

Total deficiency in precipitation during the month, at Pittsburgh, 0·50 inches.

Total excess in precipitation during the month, at Philadelphia, 0·93 inches.

Total excess in precipitation since January 1st, at Pittsburgh, 3·00 inches.

Total excess in precipitation since January 1st, at Philadelphia, 8·81 inches.

WIND AND WEATHER.

No severe gales passed over the State during the month. The weather was cold and wet.

Average Number.—Rainy days, 10; clear days, 8; fair days, 9; cloudy days, 14.

Prevailing Direction of Wind.—Northwest.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Charlesville, 11th; Reading, 12th; Blue Knob, 12th; Le Roy, 1st, 27th; Quakertown, 1st, 12th; Johnstown, 12th; Emporium, 1st, 12th; State College, 1st; West Chester, 1st, 12th; Rimersburg, 12th; Grampian Hills, 12th; Catawissa, 1st, 12th, 27th; Carlisle, 12th; Swarthmore, 1st; Uniontown, 31st; Huntingdon, 1st; Petersburg, 1st; Indiana, 12th; Lancaster, 1st; Myerstown, 1st, 12th; Annville, 1st, 27th; Wilkes-Barre, 1st; New Bloomfield, 12th; Philadelphia, 1st, 12th; Girardville, 1st, 12th; Selins Grove, 1st, 12th, 13th, 27th; Eagles Mere, 1st; Wellsboro, 1st, 27th; Columbus, 1st, 3d, 13th; Canonsburg, 31st; Dyberry, 1st, 12th; South Eaton, 1st; Gettysburg, 12th; Centre Valley, 1st, 12th.

Hail.—Blue Knob, 18th; Emporium, 1st; State College, 1st; Catawissa, 1st; Philadelphia, 1st; Girardville, 15th; South Eaton, 1st; Centre Valley, 12th.

Snow.—Charlesville, 23d; Reading, 23d; Blue Knob, 6th, 23d; Hollidaysburg, 23d; Le Roy, 7th, 23d; Forks of Neshaminy, 23d; Quakertown, 23d; Johnstown, 7th, 23d; Emporium 7th; State College, 8th, 23d; Phillipsburg, 22d; West Chester, 23d; Coatesville, 1st; Kennett Square, 23d; Rimersburg, 7th; Grampian Hills, 23d; Carlisle, 23d; Harrisburg, 23d; Swarthmore, 23d; Chambersburg, 23d; McConnellsburg, 23d; Huntingdon, 23d; Petersburg, 23d; Indiana, 7th, 23d; Lancaster, 23d; Myerstown, 23d; Annville, 23d; Drifton, 23d; Wilkes-Barre, 23d; Greenville, 7th; Pottstown, 23d; New Bloomfield, 23d; Philadelphia, 23d; Girardville, 22d; Selins Grove, 7th, 23d; Eagles Mere, 7th, 22d; Wellsboro, 7th, 14th, 22d; Dyberry, 23d; Honesdale, 22d; York, 23d; Gettysburg, 23d; Centre Valley, 23d; Westtown, 23d; Nisbet, 23d.

Frost.—Pittsburgh, 15th, 16th, 19th, 21st, 23d, 24th; Charlesville, 3d, 5th,

RVICE FOR OCTOBER, 1889.

TATION.		NUMBER OF DAYS.			WIND.			
					PREVAILING DIRECTION.			
Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	OBSERVERS.
. . .	10	7	2	22	NE	. . .	SE	Prof. E. S. Breidenbaugh.
. . .	14	7	10	14	N	N	N	Oscar D. Stewart, Sgt. Sig. Corps
. . .	. . .	6	17	8	W	N	NW	Rev. A. Thos. G. Apple.
. . .	11	7	11	13	NW	NW	NW	C. M. Dechant, C.E.
. . .	. . .	. . .	. . .	. . .	. . .		. . .	Dr. Charles B. Dudley.
. . .	12	4	13	14	NW	NW	NW	A. H. Boyle.
. . .	10	12	9	10	NW	W	W	Prof. J. A. Stewart.
. . .	9	10	2	19	NW	NW	NW	Charles Beecher.
. . .	13	8	6	17	W	SW	N	Geo. W. T. Warburton.
. . .	11	8	8	15	NW	NW	NW	J. C. Hilsman.
. . .	17	4	15	12	NE	NE	N	J. L. Heacock.
. . .	13	8	13	10	NW	NW	NW	E. C. Lorentz.
. . .	7	9	8	14	W	N	NW	T. B. Lloyd
. . .	8	. . .	. . .	. . .	. . .	. . .	. . .	John J. Boyd.
. . .	12	4	15	12	W	W	W	Prof. Wm. Frear.
. . .	10	9	6	16	SW	SW	SW	Geo. H. Dunkle.
. . .	14	13	4	14	N	NW	NW	Jesse C. Green, D.D.S.
. . .	13	10	9	12	W	W	W	W. T. Gordon.
. . .	11	13	7	11	N	N	N	Benj. P. Kirk.
. . .	11	9	8	14	W	W	W	Prof. Wm. F. Wickersham.
. . .	9	6	12	13	NW	NW	W	Rev. W. W. Deatrick, A.M.
. . .	2	9	8	14	SW	NW	SW	C. M. Thomas, B.S.
. . .	9	8	10	13	W	W	W	Nathan Moore.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. John A. Robb.
. . .	9	. . .	. . .	. . .	. . .	. . .	. . .	Robert M. Graham.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	R. B. Derickson.
. . .	9	7	12	12	W	N	N	J. E. Pague.
. . .	13	7	11	13	N	N	N	Frank Ridgway, Sgt. Sig. Corps.
. . .	7	1	9	21	NW	NW	NW	Prof. Susan J. Cunningham.
. . .	12	7	9	15	SW	SW	SW	Peter Wood, Sgt. Sig. Corps.
. . .	10	12	14	5	NW	NW	NW	Wm. Hunt.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	R. L. Haslet.
. . .	5	8	9	14	. . .	. . .	. . .	Miss Mary A. Ricker.
. . .	6	11	9	11	W	W	W	Thomas F. Sloan.
. . .	11	13	9	9	W	W	W	Prof. W. J. Swigart.
. . .	9	2	17	12	W	W	W	J. E. Rooney.
. . .	11	5	11	15	NW	N	NW	Prof. S. C. Schmucker.
. . .	13	6	14	11	W	W	W	E. E. Weller.
. . .	5	6	9	16	W	W	W	Wm. T. Butz.
. . .	14	6	6	19	NW	NW	NW	Wm. H. Kline.
. . .	. . .	7	11	13	W	W	W	Geo. W. Bowman, A.M., Ph.D.
. . .	13	3	18	10	N	NW	NW	H. W. Mullen.
. . .	9	. . .	. . .	. . .	NW	NW	NW	H. D. Miller, M.D.
. . .	9	11	4	16	NE	NE	NE	A. W. Betterly.
. . .	9	. . .	. . .	. . .	. . .	. . .	. . .	John S. Gibson, P. M.
. . .	10	7	6	18	NE	NE	NE	Prof. S. H. Miller.
. . .	11	9	8	14	NW	NW	NE	Charles Moore, D.D.S.
. . .	8	17	2	12	W	W	SE	Lerch & Rice.
. . .	9	8	8	15	W	W	W	Frank Mortimer.
. . .	13	10	7	14	NW	NW	NW	Luther M. Dey, Sgt. Sig. Corps.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	C. L. Peck.
. . .	12	10	9	12	NW	NW	NW	E. C. Wagner.
. . .	12	4	15	12	NW	NW	NW	J. M. Boyer,
. . .	10	9	11	11	NW	NW	NW	W. M. Schrock.
. . .	12	6	11	14	NW	SW	SW	E. S. Chase.
. . .	14	6	10	15	N	N	N	H. D. Deming.
. . .	6	8	10	13	NE	NE	NE	F. O. Whitman
. . .	12	8	5	18	N	N	N	Wm. Loveland.
. . .	16	13	10	8	SW	SE	SE	A. L. Runion.
. . .	11	5	13	13	W	NW	NW	Theodore Day.
. . .	9	. . .	. . .	. . .	. . .	. . .	. . .	John Torrey.
. . .	12	9	5	17	N	N	N	Benj. M. Hall.
. . .	9	12	9	10	NW	NW	NW	Mrs. L. H. Grenewald.

T. F. TOWNSEND, *Sergeant Signal Corps, Assistant.*

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for October, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction. 7 A. M.	2 P. M.	9 P. M.	Observers.
Adams,[1]	Gettysburg (24 days),	624	...	...	...	49·7	79·0	12	26·0	24	58·4	40·4	18·0	44·0	12	4·0	24	...	...	4·16	1·50	...	10	7	2	22	NE	...	SE	Prof. E. S. Bre[illegible]
Allegheny,[1]	Pittsburgh,	847	30·088	30·392	29·707	51·0	75·0	11	30·0	24	53·3	42·7	16·6	33·0	19	2·0	13	75·8	41·3	2·06	...	...	14	7	10	14	N	N	N	Oscar D. Stewart, Sgt. Sig. Corps.
Bedford,	Charlesville,	1,300	...	...	...	47·2	...	...	...	...	...	...	...	...	...	...	...	79·2	41·6	...	...	...	...	6	17	8	W	N	NW	Rev. A. Thos. G. Apple.
Berks,[1]	Reading,	304	30·051	30·405	29·664	49·8	75·0	1	27·0	22	60·3	39·3	21·0	36·0	17	6·0	31	90·6	47·0	5·74	...	...	11	7	11	13	NW	NW	NW	C. M. Dechant, C.E.
Blair,[2]	Altoona,	1,181	...	...	...	51·2	71·0	2, 11	26·0	24	59·9	42·6	17·3	29·0	13	6·0	27	65·4	39·1	2·38	...	...	...	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Blue Knob,	2,100	...	...	...	44·8	70·0	11	22·0	24	...	...	...	...	...	...	...	...	...	4·30	3·60	...	12	4	13	14	NW	NW	NW	A. H. Boyle.
Blair,	Hollidaysburg,	947	...	...	...	41·0	76·0	11	17·0	24	60·0	35·0	25·0	44·0	19	9·0	29	83·0	35·5	2·90	...	...	10	12	9	10	NW	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718	30·074	30·488	29·624	43·7	70·5	1	16·0	24	53·9	34·4	19·5	39·0	19	3·5	13	82·7	38·6	3·16	...	...	9	10	2	19	NW	NW	NW	Charles Beecher.
Bradford,	Le Roy,	1,400	...	...	...	42·7	66·0	12	20·0	24	49·8	36·7	13·1	30·0	19	2·0	30	...	...	4·73	1·90	...	13	8	6	17	W	SW	N	Geo. W. T. Warb[illegible]
Bucks,	Forks of Neshaminy,	...	...	...	...	49·8	...	...	...	...	...	...	...	...	...	...	...	...	...	4·77	...	...	11	8	8	15	NW	NW	NW	J. C. H[illegible]
Bucks,	Quakertown,	536	30·050	30·390	29·560	47·4	77·5	12	26·5	25	59·4	37·4	22·0	37·0	12	8·5	31	80·0	40·9	5·23	...	...	17	4	15	12	NE	NE	N	J. L. Heacock.
Cambria,	Johnstown,	1,184	30·076	30·370	29·723	47·1	73·0	3, 11	21·0	24	58·8	37·5	21·3	38·0	19	5·0	29	...	...	2·55	1·00	...	13	8	13	10	NW	NW	NW	E. C. Lorentz.
Cameron,	Emporium,	1,030	...	...	...	46·3	69·0	11	15·0	24	56·8	33·9	22·9	45·0	19	9·0	31	...	...	3·70	...	...	7	9	8	14	W	N	NW	T. B. Lloyd.
Carbon,[1]	Mauch Chunk (19 days),	550	...	...	...	46·8	74·5	20	24·0	24	56·3	37·3	19·0	37·5	17	4·5	31	...	...	4·95	...	...	8	...	...	...	...	...	...	John J. Boy[illegible]
Centre,	State College— Agricultural Experiment Station,	1,191	30·032	30·404	29·507	46·0	72·0	11	20·0	24	54·6	37·3	17·3	31·0	19	4·0	30	75·3	38·0	3·36	...	...	12	4	15	12	W	W	W	Prof. Wm. Frear.
Centre,	Phillipsburg,	1,350	...	...	...	44·0	75·0	11	14·0	24	56·1	33·0	23·1	45·0	11	7·0	27	...	...	3·54	...	...	10	9	6	16	SW	SW	SW	Geo. H. Dunkle.
Chester,	West Chester,	455	30·028	30·372	29·541	49·9	80·0	12	28·0	24	59·6	41·7	17·9	29·5	17	7·0	29	71·0	41·2	4·97	...	...	14	13	4	14	N	NW	NW	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	48·3	83·0	12	29·0	22, 24	61·2	38·7	22·5	41·0	11	8·0	30	...	...	4·61	1·00	...	13	10	9	12	W	W	W	W. T. Gordon.
Chester,[1]	Kennett Square,	275	...	...	...	50·0	...	...	...	...	...	...	...	...	...	...	...	...	...	5·04	...	...	11	13	7	11	N	N	N	Benj. P. Kirk.
Chester,[1]	Westtown,	350	...	...	...	49·4	80·0	12	26·5	24	60·8	38·0	22·8	42·0	11	13·5	14	...	...	5·37	·50	...	11	9	8	14	W	W	W	Prof. Wm. F. W[illegible]
Clarion,	Rimersburg,	1,500	...	...	...	46·0	71·0	11	23·0	24	52·0	39·0	13·0	25·0	24	2·0	28	...	...	...	...	...	9	6	12	13	NW	NW	W	Rev. W. W. Deatr[illegible]
Clarion,	Clarion— State Normal School,	1,530	...	...	...	45·8	71·5	11	19·0	24	55·3	35·6	19·7	38·0	11	1·0	30	78·3	39·0	2·17	...	...	2	9	8	14	SW	NW	SW	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	...	...	...	45·0	70·0	11	20·0	26	50·9	38·1	12·8	36·0	5	2·0	13	...	...	3·21	...	...	9	8	10	13	W	W	W	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. John A. Ro[illegible]
Columbia,	Catawissa,	491	...	...	...	48·0	70·0	1	25·0	24	...	...	...	...	...	...	...	...	...	2·82	...	...	9	...	...	...	...	...	...	Robert M. Graham.
Crawford,	Meadville— Allegheny College,	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. B. Derickson.
Cumberland,	Carlisle,	480	...	...	...	50·1	78·0	11	22·5	24	61·9	41·9	20·0	36·0	17	4·5	30	82·7	41·9	3·75	...	...	9	7	12	12	W	N	N	J. E. Pague.
Dauphin,[1]	Harrisburg,	361	30·080	30·431	29·326	50·1	76·0	11	29·0	24	57·8	42·5	15·3	34·0	11	3·0	28	79·6	42·2	3·33	...	...	13	7	11	13	N	N	N	Frank Ridgway, Sgt. Sig. Corps.
Delaware,	Swarthmore— Swarthmore College,	190	30·027	30·355	29·641	50·1	79·3	12	32·0	24	59·7	41·3	18·4	41·3	12	7·9	29	77·0	42·6	5·20	...	...	7	1	9	21	NW	NW	NW	Prof. Susan J. Cunningham.
Erie,[1]	Erie,	681	30·000	30·480	29·580	46·0	69·0	3	30·0	24	52·0	40·0	12·0	27·0	3	3·0	28	75·0	38·0	3·37	...	...	12	7	9	15	SW	SW	SW	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	30·008	30·258	29·684	50·1	75·0	5	25·0	24	58·3	41·2	17·1	38·0	5	3·0	28	79·0	44·0	3·31	...	...	10	12	14	5	NW	NW	NW	Wm. Hunt.
Forrest,	Tionesta,	1,057	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. L. Haslet.
Franklin,[1]	Chambersburg— Wilson Female College,	618	30·110	30·394	29·763	47·9	78·0	11	23·0	24	58·1	37·1	21·0	40·0	17	8·0	29	82·4	43·4	3·24	...	...	5	8	9	14	...	...	...	Miss Mary A. R[illegible]
Fulton,	McConnellsburg,	875	...	...	...	48·2	77·0	11, 12	26·0	9	60·4	37·7	22·7	42·0	11	7·0	30	76·9	41·0	3·14	·50	...	6	11	9	11	W	W	W	Thomas F. Sloan.
Huntingdon,[1]	Huntingdon— The Normal College,	650	...	...	...	46·5	76·0	11	18·0	24	60·4	36·2	24·2	43·0	11	5·0	30	...	...	3·67	1·00	...	11	13	9	9	W	W	W	Prof. W. J. Swigart.
Huntingdon,	Petersburg,	700	...	...	...	46·5	76·0	11, 20	20·0	24	57·1	38·3	18·8	40·0	20	4·0	7	...	...	3·34	·50	...	9	2	17	12	W	W	W	J. E. Rooney.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	47·1	72·6	11	21·3	24	60·0	31·0	29·0	39·6	14	10·0	30	73·2	43·7	3·52	...	...	11	5	11	15	NW	N	NW	Prof. S. C. Schmucker.
Lancaster,	Lancaster,	411	30·062	30·364	29·627	49·7	80·0	12	27·0	24	59·5	39·3	20·2	37·0	11	6·0	30	89·0	46·9	3·88	...	...	13	6	14	11	W	W	W	E. F. Weller.
Lawrence,	New Castle,	932	...	...	...	48·0	73·0	11	17·0	24	56·7	35·0	21·7	43·0	19	6·0	30	...	...	1·88	...	...	5	6	9	16	W	W	W	Wm. T. Butz.
Lebanon,	Myerstown,	474	30·018	30·342	29·585	47·8	76·0	12	26·8	24	63·3	38·5	24·8	34·0	11	5·9	30	84·9	43·6	4·47	...	...	14	6	6	19	NW	NW	NW	Wm. H. Kline.
Lebanon,	Annville— Lebanon Valley College,	339	...	...	...	53·6	82·0	12	32·0	24	...	...	...	...	...	...	...	78·1	46·2	...	...	...	...	7	11	13	W	W	W	Geo. W. Bowman, A.M., Ph.D.
Lehigh,	Centre Valley,	348	...	...	...	53·5	82·0	12	30·0	24	65·0	40·0	25·0	42·0	19	4·0	28	...	...	3·09	...	...	13	3	18	10	N	NW	NW	H. W. Millen.
Luzerne,	Drifton— Drifton Hospital,	1,655	...	...	...	45·0	68·0	1	26·0	24	55·1	36·5	18·6	30·0	3	9·0	13	...	...	5·74	...	...	9	...	...	...	NW	NW	NW	H. D. Miller, M.D.
Luzerne,[1]	Wilkes-Barre,	575	...	...	...	49·0	75·0	15	23·0	24	59·0	39·0	20·0	37·0	19	5·0	30	...	...	3·16	...	...	9	11	4	16	NE	NE	NE	A. W. Betterly.
Lycoming,[1]	Nisbet,	550	...	...	...	45·1	...	...	...	...	...	...	...	...	...	...	...	...	...	4·20	...	...	9	...	...	...	...	...	...	John S. Gibson, P. M.
Mercer,[1]	Greenville— Thiel College,	1,000	30·001	30·347	29·598	42·2	74·0	11	19·3	24	55·6	35·6	20·0	38·3	19	5·0	30	94·1	40·7	2·74	...	...	10	7	6	18	NE	NE	NE	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	...	...	...	51·0	79·0	12	30·0	24	59·0	43·0	16·0	31·0	17	5·0	14	76·0	43·8	4·56	...	...	11	9	8	14	NW	NW	NE	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	...	...	...	51·0	73·0	1	28·0	24	59·0	40·0	19·0	33·0	17	4·0	6	73·0	44·0	3·29	...	...	8	17	2	12	W	W	SE	Lerch & Rice.
Perry,	New Bloomfield,	400	...	...	...	47·4	75·0	12, 20	20·0	24	58·7	36·3	22·4	39·0	17	6·0	31	...	...	4·35	1·00	...	9	8	8	15	W	W	W	Frank Mortimer.
Philadelphia,[1]	Philadelphia,	117	30·056	30·400	29·560	52·8	79·0	12	32·0	23	60·1	45·4	14·7	26·0	12	4·0	13	72·0	42·0	3·76	...	...	13	10	7	14	NW	NW	NW	Luther M. Dey, Sgt. Sig. Corps.
Potter,	Coudersport,	1,670	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. L. Peck.
Schuylkill,	Girardville,	1,000	30·082	30·424	29·679	46·5	70·0	1, 12	25·0	24	56·3	38·0	18·3	20·0	11	7·0	31	...	...	4·41	...	...	12	10	9	12	NW	NW	NW	E. C. Wagner.
Snyder,	Selins Grove,	445	...	...	...	48·9	69·0	20	22·0	24	61·4	32·4	29·0	47·0	11	10·0	30	74·8	41·0	3·65	...	...	12	4	15	12	NW	NW	NW	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	44·6	73·0	12	17·0	24	57·1	34·2	22·9	38·0	20	9·0	7	87·9	39·9	2·61	...	...	10	9	11	11	NW	NW	NW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	30·119	30·520	29·643	41·7	66·0	27	18·0	24	47·5	34·7	12·8	24·0	24	3·0	29	80·2	35·0	8·61	·50	...	12	6	11	14	NW	SW	SW	E. S. Chase.
Tioga,	Wellsboro,	1,327	30·050	30·444	29·540	40·9	65·0	19	13·0	24	50·8	31·8	19·0	34·0	24	2·0	30	73·2	32·4	5·61	...	...	14	6	10	15	N	N	N	H. D. Deming.
Union,[1]	Lewisburg,	450	...	...	...	44·2	69·6	20	20·0	24	54·1	34·2	19·9	41·0	21	10·0	13	...	...	3·04	...	...	6	8	10	13	NE	NE	NE	F. O. Whitman.
Warren,	Columbus,	1,410	...	...	...	43·0	68·0	16	14·0	24	52·3	33·7	18·6	42·0	16	2·0	28	...	...	3·44	...	...	12	8	5	18	N	N	N	Wm. Loveland.
Washington,	Canonsburg,	950	...	...	...	45·0	74·0	11, 12	23·0	24	60·0	35·5	24·5	40·0	11	6·0	30	80·4	33·6	2·37	...	...	16	13	10	8	SW	SE	SE	A. L. Runion.
Wayne,	Dyberry,	1,100	...	...	...	41·7	70·0	12	14·0	24	53·7	32·9	20·8	42·0	19	3·0	29	...	...	4·03	...	...	11	5	13	13	W	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	45·4	68·0	12	18·0	24	54·0	36·7	17·3	36·0	19	4·0	29	63·3	41·3	4·02	...	...	9	...	...	...	...	...	...	John Torrey.
Wyoming,[1]	South Eaton	660	...	...	...	45·0	70·0	1	20·5	24	54·7	35·3	13·4	27·5	24	4·0	29	...	...	4·11	...	...	12	9	5	17	N	N	N	Benj. M. Hall.
York,[1]	York,	385	30·049	30·402	29·744	49·9	80·0	12	27·5	24	62·1	39·3	22·8	38·0	12	6·0	30	76·7	42·0	4·03	...	...	9	12	9	10	NW	NW	NW	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

		Swarthmore.	Philadelphia.	Seisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Nesham'y.	Germantown.	Point Pleasant.	Bethlehem.	Canonsburg.	Carlisle.	Centre Valley.	McConnellsburg.	Westtown.	Lewisburg.
1	5	·14	·16	·23	. .	·10	·23	·25	·60	·27	. .	·01	·01	·05	·08	. .	·15	. .	·03
2	.	. .	. .	·08	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·02	. .	. .	. .	. .
3	.	. .	. .	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
4	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
5	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .
6	5	. .		·32	. .	·23	·18	·16	. .	·08	. .	·17	·02	·01	. .	. .	. .	·10	. .
7	1	. .	·01	. .	·13	. .	. .	. .	·30	. .	. .	. .	. .	·03	. .	. .	. .	. .	. .
8	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
9	.	. .	. .	. .	. .	·02	. .	. .	. .	·03	. .	. .	. .	. .	. .	. .	. .	. .	. .
10	2	·03	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
11	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
12	6	. .	·04	·62	·55	·54	·55	1·01	·18		. .	·6[illegible]	·57	·55	. .	·44	. .	. .	. .
13	0	. .	·12		. .	·23	. .	. .	. .	·43	. .	. .	. .	·05	·24	·08	·46	. .	·70
14	4	·47	·39	·55	. .	·53	. .	. .	·85	. .	. .	. .	·41	·05	·67	·23	·20	. .	·25
15	4	1·24	·83	·18	·82	. .	·59	·73	. .	·80	. .	·59	. .	. .	. .	·16	. .	1·45	. .
16	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1·42	. .
17	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
18	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
19	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
20	5	. .	. .	. .	. .	·53	. .	·4[illegible]	. .	. .	. .	. .	·09	. .	. .	. .	. .	. .	. .
21	6	·26	·19	·21	·57	. .	·56	. .	·35	·24	. .	·60	. .	. .	. .	. .	. .	. .	. .
22	4	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·06	·35	. .	·18	. .	. .	·23
23	22	·51	·32	·21	·34	·18	·27	·04	·41	·38	. .	·29	. .	·35	·85	. .	·91	·40	. .
24	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·13	. .	. .	. .
25	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·03	. .	. .	. .	. .	. .
26	22	. .	·15	. .	. .	1·08	. .	. .	. .	·01	. .	. .	. .	·32	·26	. .	. .	. .	·30
27	14	2·64	1·45	. .	1·03	·60	. .	2·45	1·85	2·01	. .	2·60	2·03	·45	1·26	. .	1·20	. .	1·53
28	07	. .	·06	2·63	·06	. .	2·40	. .	. .	·05	. .	. .	. .	·12	·30	1·70	. .	2·00	. .
29	.	. .	·02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·03	. .	·04	. .	. .	. .
30	.	. .	. .	. .	. .	. .	. .	. .	·48	. .	. .	. .	·10	·22		. .	. .	. .	. .
31	15	. .	·02	·14	·22	·15	·19	·22	. .	·12	. .	·18	. .	·24	·07	·13	·22	. .	. .
	3·23	5·29	3·76	5·17	4·62	5·09	4·09	4·27	5·02	4·42	. .	5·06	3·29	2·87	3·75	3·09	3·14	5·37	3·[illegible]4

T. F. T.

PRECIPITATION FOR OCTOBER, 1889.

Day	Erie.	New Castle.	Greenville	Columbus.	Pittsburgh.	Uniontown.	Clarion.	Indiana.	Johnstown.	Somerset.	Grampian Hills	Emporium.	Blue Knob.
1	.45		.43	.56	.04			.30	.10	.22	.66	.70	.50
2		.68	.04	.08				.12					.10
3	.08			.18									
4				.01									
5					.04		.62				.18		
6	.68		.07	.13	.01	.20			.15	.20		.24	.10
7	.14	.05	.02	.12	.03	.05		.05	.03	.08			.10
8					.02								.10
9													
10													
11				.02									
12	.84	.60	1.23	.71	.60	.10		.43	.16	.12	80	.83	
13					.09	.20	1.55	.51	.29	.33		.57	.50
14	.14				.04	.16			.02	.06	.05		.20
15													
16													
17													
18													
19													
20													
21													
22					.20	.52			.25		.18		.10
23					.08	.34		.31	24	.21			.50
24													
25	.01		.12										
26	.05	.60	.24	.30	.22	.28			.24	.80	.42		
27	.50		.25	.85	.18	1.00		.87	.76	.50	.64	.55	1.40
28	.34	.55	.19	.33	.31	.46			.15	.09	.28	.53	.50
29	.01							.85	.01				
30													
31	.13		.15	.15	.20			.08	.15			.28	.20
Total	3.37	1.88	2.74	3.44	2.06	3.31	2.17	3.52	2.55	2.61	3.21	3.70	4.30

Day	Phillipsburg.	Petersburg.	Huntingdon.	Hollidaysburg.	Altoona.	Chambersburg.	State College	York.	Lock Haven.	New Bloomfield.	Wellsboro.	Harrisburg.	Selins Grove.
1	.35	.13	.17	.11	.12		.32			.15	1.46	.22	.20
2	.70				.21						.05	.01	
3													
4													
5			.13		.25						.08		
6	.08	.70		18			.13				.16	.02	.05
7													
8													
9													.02
10		.10			.03								.05
11	.05				.03		.01						
12			.20	.15		.20	.45			.06	.65	.23	.20
13	.45	.20	.40	.29	.25	.60	.21			.64	.46	.28	.58
14	.15				.12		.03	1.38		.15		.35	.30
15			.02					.35					
16													
17													
18													
19													
20													
21								.10				.04	
22			.35	.28		.90	.32	.10			.05	.14	
23	.39	.62		.33	.23		.10	.80		.65		.38	.32
24													
25													
26		.25	.60	.38			.38	.40		.70	.10	.58	.43
27	.85	1.18	1.55	1.00	.32	1.40	1.09	.75		1.65	2.16	.96	.90
28	.45		.15	.03	.68		.20	.05		.25	.40	.06	.50
29													
30													
31	07	.16	.10	.15	.14	.14	.12	.10		.10	.04	.06	.10
Total	3.54	3.34	3.67	2.90	2.38	3.24	3.36	4.03	. .	4.35	5.61	3.33	3.65

Day	Lancaster.	Le Roy.	Eagles Mere.	Myerstown.	Wysox.	Catawissa.	Girardville.	Wilkes-Barre.	South Eaton.	Drifton.	Reading.	Pottstown.	West Chester.	Coatesville.
1	.10	.56	1.48	.52	.25	.36	.26	.33	.34	.88	.38	.12	.07	.05
2		.01												
3														
4			.02											
5					.38									
6	.06	.16	.34	.11		.15	.18	.32	.39	.19	.15	.12	.10	.05
7									.10				.03	
8														
9			.28		.05			.04						
10		.09	.92	.01		.02	.04		.05					
11						.02	.02	.01						
12	.03	.06	1.01	.36	.91	.35		.03	.23	.90		.20	.09	.08
13	.40	1.08	1.32	.41	.10	.60	.92	.93	.54	.32	.95	.22	.17	.23
14	.48	20		.48					.22		.48	.40	.78	.59
15	.32			.31			.03				.24	.22	.45	.30
16														
17														
18														
19														
20												.50		
21	.30			.03									.25	.32
22	.05		.06	.25	.09		.20				.35		.08	.06
23	.67	.19		.13		.10	.07	.11	.10	.10	.43	.40	.62	.55
24														
25														
26	.51		.46	.70	64	.55	.84		.03	.54	.42	.50	.28	.30
27	.82	1.25	1.50	1.03	1.38	.75	1.48	1.30	1.75	2.08	1.33	1.70	1.83	1.90
28	.05	1.01	.96	.04		.02	.13		.25	.22	.92		.14	.02
29		.06												
30		.02		.09										
31	.09	.04	.26		.04		.24	.09	.11	.51	.09	.18	.08	.07
Total	3.88	4.73	8.61	4.47	3.84	2.82	4.41	3.16	4.11	5.74	5.74	4.56	4.97	4.61

Day	Kennett Square.	Dyberry.	Honesdale.	Quakertown.	Swarthmore.	Philadelphia.	Seisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.
1	.06	.36	.50	.35	.14	.16	.23		.10	.23	.25	.60
2							.08					
3												
4												
5												
6	.02	.57	.49	.15			.32		.23	.18	.16	
7				.01		.01		.13				.30
8												
9									.02			
10		.08	.08	.02	.03					.02		
11				.01								
12		.05	1.05	.46		.04	.62	.55	.54	.55	1.01	.18
13		.38	.07	.20		.12			.23			
14	.79			.34	.47	.39	.55		.53			.85
15	.54			.34	1.24	.83	.18	.82		.59	.73	
16												
17												
18												
19												
20				.05					.53		.41	
21	.25		.09	.46	.26	.19	.21	.57		.56		.35
22	.01			.04								
23	.73	.10		.22	.51	.32	.21	.34	.18	.27	.04	.41
24												
25												
26	.19	.23	.50	.22		.15			1.98			
27	2.25	1.03	1.03	2.14	2.64	1.45		1.03	.60		2.45	1.85
28	.19	.35		.07		.06	2.63	.06		2.40		
29						.02						
30												.48
31	.01	.28	.21	.15		.02	.14	.22	.15	.19	.22	
Total	5.04	4.03	4.02	5.23	5.29	3.76	5.17	4.62	5.09	4.09	4.27	5.02

Day	Forks of Neshamiy.	Germantown.	Point Pleasant.	Bethlehem.	Canonsburg.	Carlisle.	Centre Valley.	McConnellsburg.	Westtown.	Lewisburg.
1	.27		.01	.01	.05	.05		.15		.03
2						.02				
3										
4										
5					.02					
6	.08		.17	.02	.01				.10	
7					.03					
8										
9	.03									
10										
11										
12			.62	.57	.55		.44			
13	.43				.05	.24	.08	.46		[illegible]
14				.41	.05	.67	.23	[illegible]		.25
15	.80		.59				.16		1.15	
16									[illegible]	
17										
18										
19										
20				.09						
21	.21		.60							
22				.06	.35		.18			[illegible]
23	.38		.29		.35	.85		.01	.40	
24							.13			
25					.03					
26	.01				.32	.26				.30
27	2.01		2.60	2.03	.45	1.26		1.20		1.53
28	.05				.12	.30	1.70		2.00	
29					.03		.04			
30				.10	.22					
31	.12		.18		.24	.07	.13	.22		
Total	4.42	. .	5.06	3.29	2.87	3.75	3.09	3.14	5.37	[illegible]

T. F. T.

8th, 15th, 16th, 19th, 22d, 24th; Reading, 9th, 16th, 17th, 22d; Blue Knob, 3d, 18th, 19th; Hollidaysburg, 9th, 15th, 24th; Wysox, 3d, 5th, 8th, 9th, 10th, 11th, 15th, 16th, 17th, 18th, 19th, 22d, 23d, 24th, 25th; Le Roy, 3d, 5th, 7th, 9th, 16th, 19th, 20th, 21st, 22d, 23d, 24th, 25th; Forks of Neshaminy, 8th, 9th, 17th, 22d; Quakertown, 3d, 5th, 9th, 17th, 19th, 22d, 24th, 25th; Johnstown, 3d, 5th, 9th, 16th, 17th, 19th, 22d, 24th, 25th; Emporium, 9th, 15th, 16th, 17th, 19th, 21st, 22d, 24th; State College, 3d, 5th, 9th, 15th, 16th, 19th, 22d; Phillipsburg, 3d, 9th, 15th, 16th, 19th, 22d, 24th; West Chester, 3d, 9th; Coatesville, 3d, 5th, 8th, 9th, 11th, 17th, 18th, 19th, 22d; Kennett Square, 9th; Rimersburg, 5th, 15th, 16th, 21st, 23d, 24th; Grampian Hills, 3d, 5th, 9th, 15th, 19th; Catawissa, 3d, 5th, 9th, 16th, 17th, 19th, 22d, 24th, 25th; Carlisle, 5th, 6th, 9th, 18th, 22d; Harrisburg, 23d, 24th; Erie, 16th, 18th, 21st; Uniontown, 3d, 15th, 16th, 19th; Chambersburg, 3d, 4th, 5th, 9th, 16th, 17th, 18th, 19th; McConnellsburg, 3d, 5th, 9th, 24th; Huntingdon, 9th, 16th, 17th, 19th, 22d, 24th; Petersburg, 5th, 6th, 19th, 22d, 24th; Lancaster, 3d, 4th, 5th, 9th, 17th, 19th, 22d, 24th; New Castle, 9th, 15th, 19th, 24th; Myerstown, 3d, 5th, 7th, 9th, 17th, 19th, 22d, 24th; Annville, 3d, 19th, 22d, 24th; Wilkes Barre, 22d, 23d; Greenville, 9th, 15th, 16th, 19th, 21st, 22d, 23d, 24th; Bethlehem, 3d, 5th, 17th, 19th, 22d, 24th; New Bloomfield, 5th, 7th, 16th, 17th, 19th, 21st, 24th, 25th; Philadelphia, 2d, 5th, 9th, 17th, 22d; Girardville, 1st, 2d, 3d, 4th, 5th, 7th, 8th, 9th, 11th, 16th, 17th, 18th, 19th, 21st, 22d, 24th; Selins Grove, 3d, 4th, 5th, 6th, 9th, 11th, 16th, 17th, 18th, 22d, 24th, 25th; Somerset, 3d, 4th, 5th, 9th, 15th, 16th, 17th, 18th, 19th, 22d, 25th; Eagles Mere, 3d, 4th, 5th, 9th, 15th, 18th, 19th, 23d, 24th; Wellsboro, 3d, 5th, 7th, 9th, 15th, 16th, 17th, 19th, 22d, 23d, 24th; Columbus, 3d, 5th, 9th, 11th, 12th, 16th, 18th, 19th, 21st, 22d, 23d, 24th, 25th; Dyberry, 3d, 5th, 8th, 11th, 16th, 17th, 18th, 19th, 21st, 22d, 23d, 24th, 25th; Honesdale, 9th, 24th; South Eaton, 16th, 17th, 18th, 19th; York, 17th, 19th, 22d, 24th; Gettysburg, 3d, 5th, 9th, 11th, 12th, 14th, 23d, 24th, 25th, 26th, 31st; Centre Valley, 2d; Mauch Chunk, 17th, 19th; Westtown, 3d, 9th, 16th, 17th, 22d; Nisbet, 24th.

Sleet.—Blue Knob, 8th, 29th, 30th; New Bloomfield, 14th; Wellsboro, 22d.

Coronæ.—Charlesville, 5th; Reading, 6th; Greenville, 4th, 9th.

Solar Halos.—Le Roy, 3d; Philadelphia, 19th; Eagles Mere, 3d, 12th; Wellsboro, 3d.

Lunar Halos.—Le Roy, 2d; State College, 2d, 8th; West Chester, 4th; Catawissa, 8th; Petersburg, 2d; Dyberry, 8th.

Meteors.—Eagles Mere, 18th.

WEATHER FORECASTS.

Percentage of local verifications of weather and temperature signals as reported by displaymen for October, 1889:

Weather, 87 per cent.

Temperature, 90 per cent.

TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.

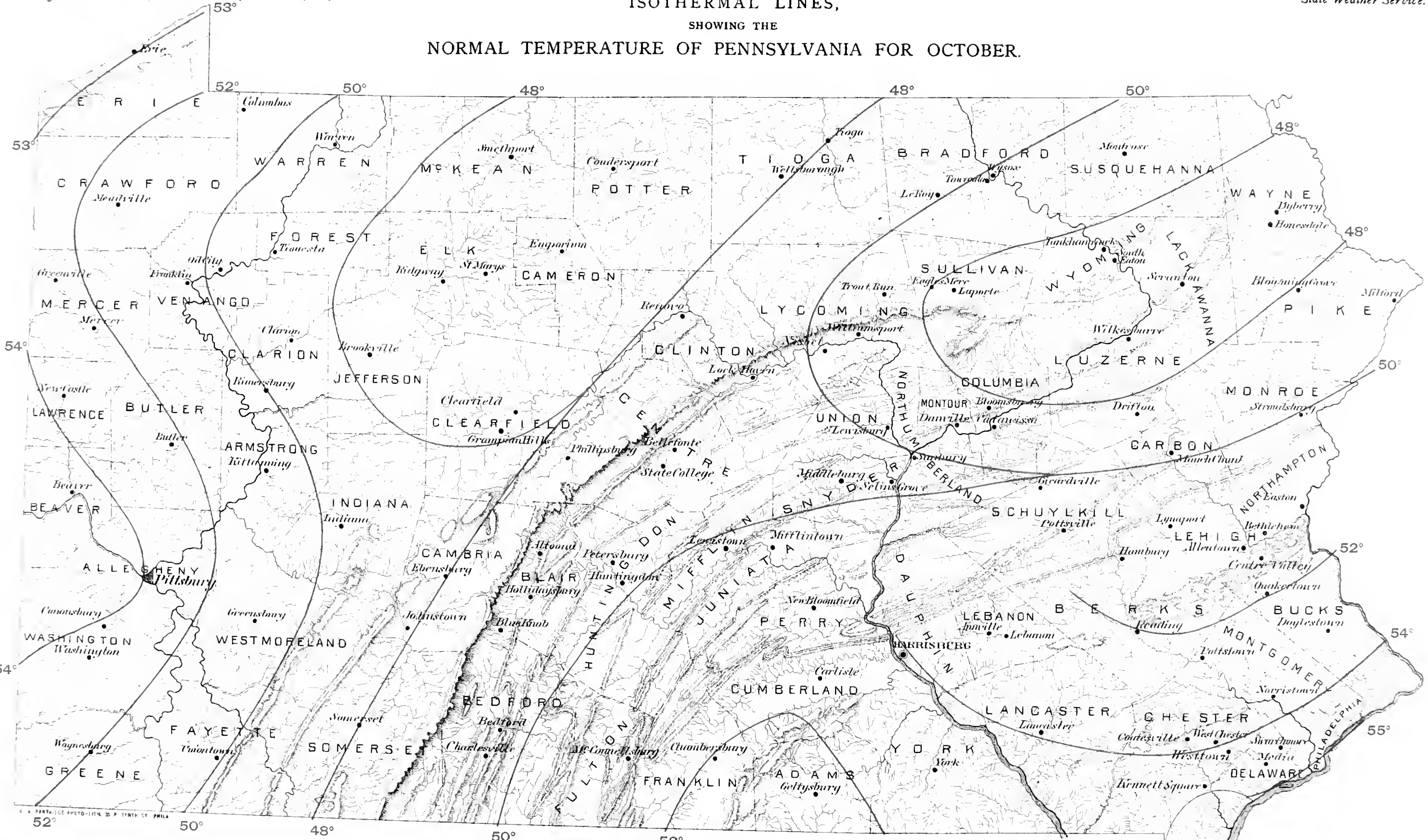
Displayman.	*Station.*
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorne.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.
W. S. Ravenscroft,	Hyndman.
R. C. Schmidt & Co.,	Belle Vernon.
Jesse R. Brown,	Lehmasters.
H. W. Mullen,	Centre Valley.
Mayer Bros.,	Bloomsburg.
E. C. Lorentz,	Johnstown.
W. M. James,	Ashland.
Miller & Allison,	Punxsutawney.
Dr. A. L. Runion,	Canonsburg.
E. J. Sellers,	Kutztown.

FOR

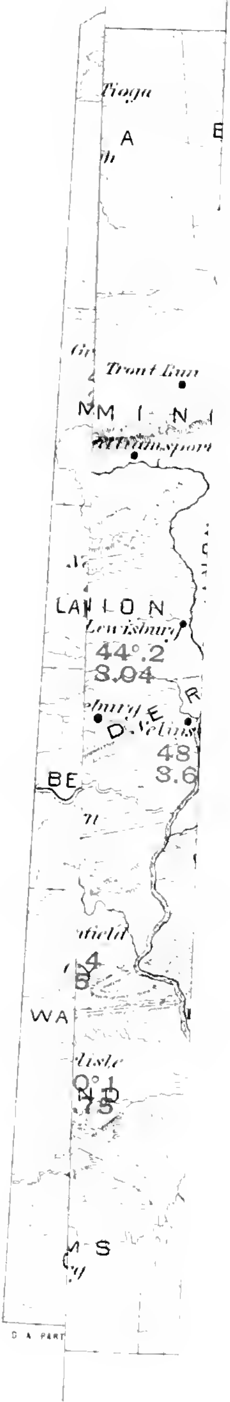
ISOTHERMAL LINES,

SHOWING THE

NORMAL TEMPERATURE OF PENNSYLVANIA FOR OCTOBER.



)R OCT



Tioga
A
Trout Run
Williamsport
LON
Lewisburg
44°.2
3.04
48
3.6
BE
WA

MEAN TEMPERATURE AND RAINFALL FOR OCTOBER. 1889.